A COMPARATIVE STUDY OF METHODS FOR CENSUSING WOODPECKERS IN SPRUCE-FIR FORESTS OF COLORADO

BY
GENE DOYLE AMMAN

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THESIS

A COMPARATIVE STUDY OF METHODS FOR CENSUSING WOODPECKERS IN SPRUCE-FIR FORESTS OF COLORADO

Submitted by

Gene Doyle Amman

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

May, 1958

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ENTITLED A COMPARATIVE STUDY OF METHODS FOR CENSUSING WOODPECKERS IN SPRUCE-FIR FORESTS OF COLORADO

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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Chapter I

INTRODUCTION

In recent years a great deal of interest has been focused on natural control factors of harmful forest insects. The use of artificial means to control these insects is becoming increasingly expensive and it is desirable to use them only when absolutely necessary. Woodpeckers are considered by forest entomologists to be the most important predator of the Engelmann spruce beetle, Dendroctonus engelmanni Hopkins (Massey and Wygant, 1954:18). This study will provide information on methods for taking censuses of woodpeckers and conditions which are most appropriate for taking a census. It is believed that if more accurate information on the numbers of woodpeckers can be obtained, a more accurate appraisal of the effectiveness of woodpeckers as an agent of biological control of the Engelmann spruce beetle will result.

Many studies have been made on methods for censusing birds; however, review of literature has failed to reveal studies specifically related to woodpeckers and to the factors involved in taking a census of woodpeckers.

Three species of woodpeckers are found in the spruce-fir forests of Colorado. These are the Hairy Woodpecker, Dendrocopos villosus; the Downy Woodpecker, Dendrocopos pubescens; and the Northern Three-toed Woodpecker, Picoides tridactylus.

These woodpeckers resemble each other a great deal, yet they are relatively easy to distinguish. The hairy woodpecker is a large bird 8.5 to 10.5 inches long and is checkered and spotted with black and white and has a white back. The males have a small red patch on the back of the head, but the red patch is absent in the females. The common call is a sharp, distinct "pleek." The hairy is the most wary of the three species and usually cannot be approached closer than 20 feet.

The downy woodpecker has almost exactly the same color pattern as the hairy but it is much smaller in size, being 6.5 to 7.0 inches in length. This woodpecker has nearly the same black and white spots and checkering as the foregoing species. A distinguishing difference is the presence of black spots on the outside tail feathers of the downy. The male downy has a red patch on the back of the head which is lacking in the female. The voice of the downy is more of a "pick" and is not as sharp as that

of the hairy. The downy is less wary than the hairy and often can be approached to within 15 feet.

The northern three-toed woodpecker is the medium sized woodpecker of the three, being 9.0 to 9.5 inches long. The males have a yellow patch on the crown of the head. This yellow patch is missing in the females. The female three-toed woodpecker looks very much like the female hairy woodpecker, both with white backs and of comparable size. A good identification mark is the heavily barred flanks of the female three-toed. The voice is a sharp "chick." The three-toed woodpecker is the least wary of the three species and is often easily approachable to within 10 feet.

These three species of woodpeckers spend a great deal of time feeding throughout the daylight hours. It is usually this food tapping and digging which attracts the census taker's attention. Few woodpeckers are seen before they are heard.

The problem

The values of each method of censusing woodpeckers need to be determined through a comparative study of methods. To make an intelligent interpretation of the results of a census, factors affecting the population of woodpeckers must be determined.

The methods of taking censuses mentioned below in the problem analysis will be described in Chapter III.

Problem analysis.--The problem may be divided into the following questions:

1. What are the relative merits of the 20-acre fixed-plot method?

2. What are the relative merits of the one-acre method?

3. What are the relative merits of the one-fourth-acre method?

4. What are the relative merits of the average-distance method?

5. How are the counts of woodpeckers affected by the number of trees with nest holes present in an area?

6. How are the counts affected by seasonal fluctuations in the population of woodpeckers of an area?

7. During various weather conditions, how are counts affected by daily fluctuations in the activity of woodpeckers?

8. What effect does the behavior of woodpeckers have on counts?

9. How are counts of woodpeckers affected by the Engelmann spruce beetle infestation?

Delimitation.--This study is limited to three areas in spruce-fir forests of Colorado. These areas were chosen to represent three classes of Engelmann spruce beetle infestation--epidemic, endemic and past epidemic. These are located at Wolf Creek Pass, Hidden Valley, and Rabbit Ears Pass, respectively. The census work is further limited to the four main methods listed in the problem analysis and to three species of woodpeckers--Dendrocopos villosus, Dendrocopos pubescens and Picoides tridactylus. The study was carried out during the period from October, 1956, to March, 1958. During this time the various areas were visited between five and eleven times. While the study of woodpecker behavior is not a primary objective of this study, certain observations are included to aid in the interpretation of the results obtained from each census.

Location and description of the study areas

Three areas were chosen in the spruce-fir forest according to the classification of bark beetle infestations at each, determined by surveys conducted by the Division of Forest Insect Research, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

In Southwestern Colorado, on the east side of Wolf Creek Pass at an elevation of approximately 10,500 feet, was an area undergoing an epidemic of the Engelmann spruce beetle in 1956. A 20-acre plot was chosen within this area, located one mile south of the highway maintenance station near the summit of the pass. This area has an eastern exposure with a moderate slope. The vegetation is primarily composed of two species of trees, Engelmann spruce, Picea engelmanni, and sub-alpine fir, Abies lasiocarpa.

An area having an endemic bark beetle population was chosen at Hidden Valley in Rocky Mountain National Park at an elevation of approximately 9,500 feet. The study plot was located one-fourth mile south of the ski house and has a northern exposure with a steep slope. Trees found in the area are mostly living and consist of the following species: Engelmann spruce, sub-alpine fir, lodgepole pine, Pinus contorta, and limber pine, Pinus flexilis.

The third plot for study was established at Rabbit Ears Pass in Northern Colorado at an elevation of approximately 9,500 feet. The 20-acre plot was located four miles west of the summit and adjacent to the south side of US Highway 40. This area has a southern exposure

and only a slight slope. Three species of trees are found on the plot. These are Engelmann spruce, subalpine fir, and lodgepole pine. This area had undergone an epidemic of the Engelmann spruce beetle commencing in 1948.

Chapter II

REVIEW OF LITERATURE

Many studies have been made on methods for the census of birds, and such studies have often discussed the biological and environmental factors which affect the counts. The problem of making a comparative study of methods for the census of woodpeckers in the spruce-fir forests of Colorado has much in common with studies on methods used for other avian species and for bird populations in general. While certain biological factors, such as breeding season, food availability, and population structure, affect the counting of all birds, others are specific for the species involved and must be taken into account to obtain a reliable estimate of the population. Perusal of literature has failed to reveal an adequate treatment of factors specifically important to counting of woodpeckers in spruce-fir forests.

For the sake of clarity and convenience, this review of literature is presented in five parts. The first section deals with literature on general considerations in taking a census of birds. The second part deals with studies using the fixed-plot method of taking a

census, the third with the strip method of taking a census, and the fourth with the small sample-plot method of taking a census. The fifth reviews literature dealing with a certain aspect of population structure, the contagious population, relevant to the counting of woodpeckers.

General considerations

In taking a census of any species of bird, certain biological and environmental factors must be taken into consideration.

The weather, the season and the time of day are known to affect the counts of birds (Leopold, 1933:141). Colquhoun (1940:56) observed that strong winds and drops in temperature reduced singing and consequently the number of birds seen. In taking early morning counts of Lesser Prairie Chickens, Davison (1940:57) found these counts to be consistent, except under adverse conditions of weather, when the birds, though present, could not be observed due to lessened activity. During a study of the Winter Wren, Troglodytes troglodytes, Phillips and Black (1956:403) did not take counts on windy days because of the difficulty in locating birds.

Kendeigh (1944:75) stated that in most species there is a decrease in numbers seen from winter to summer

and an increase again in autumn. Part of this is due to migration out of the region. With permanent residents the decrease is due to reduced visibility with the leafing out of trees and reduced singing of birds after nesting has begun.

Palmgren (1933:92) cited Nicholson as writing that in any ordinary area the bird population is not a fixed quantity but one that fluctuates from day to day or from hour to hour.

Counts may be affected by the behavior and conspicuousness of different birds. These factors can have a decided affect on the final outcome of the census. Davison (1940:55) wrote that the habits of animals vary so greatly that effective observations must be planned for the species involved.

While taking a census in slightly rolling country, Breckenridge (1935:196) found that a portion of all species of birds anticipated his course of travel and moved away from this line. He reported that such movement could be determined when the number of observations on nearer strips was significantly less than on distant strips.

In making comparisons of the relative abundance of one species with another, Winterbottom (1940:68) found

that there is a source of error from differences in conspicuousness of species and the flocking tendencies of some birds. Colquhoun and Morley (1941:37) observed that the conspicuousness of birds varies for three types of behaviour--a bird on the ground, in flight, and in singing. Einarsen (1945:121) stated that most wild species are secretive. Therefore, the same individuals will not usually be encountered each time a census is taken of the same area.

Kendeigh (1944:90) wrote that there is usually a decrease in activity and conspicuousness of birds during the middle of the day. In support of this statement, Hutchison (1952:56), while studying the effects of woodpeckers on the Engelmann spruce beetle, observed that during clear weather the woodpeckers began feeding at the first light of day and continued until 10 or 10:30 a.m. Few birds were found feeding from 10:30 a.m. to 2 p.m., when feeding began again and continued until dark. A variation in the hours of feeding was noted by Hutchison on days when it was snowing or heavily overcast. During these days feeding was light and occurred mostly during the midday hours. He observed more feeding at 10°F. than above 20°F.

Fixed-plot method

In using the fixed-plot method, a plot of definite size is usually established with several marked lines traversing it. The route taken during the census is along the lines or between the lines.

Size of plot.--Palmgren (1933:88) wrote that for heavily wooded country with a high density of bird life 40 acres are as much as one person can cover in a day. Kendeigh (1944:78) stated that a plot should contain but a single major type of community for most effective use in obtaining counts capable of comparison with other areas. Plots of about 25 acres were used by Kendeigh (1947:7) during a study in a coniferous forest biome in Ontario.

Results obtained from small uniform areas were considered more reliable than from larger mixed communities by Stewart and Aldrich (1949:76). However, Odum (1950:597) stated that small quadrats introduce error in estimating the abundance of less common species or those with larger territories.

Number of censuses.--Kendeigh (1944:90) cited Palmgren (1930) as finding that just one census of an area listed 62 percent of the total population eventually found to be present in an area. Two censuses increased

the representation to 80 percent, three counts to 91 percent, and four to 96 percent. Kendeigh recommended that five complete counts of the birds in a plot be a minimum and that these should be well spread throughout the nesting season. However, other authors feel that these counts should be taken during a short period of time soon after nesting begins. Kendeigh (1947:7) used seven censuses of each plot to determine territories and total population.

Nordberg (1947:90) stated that for woods of the open-fir type a raising coefficient of 50 percent for once-counted plots and 15 percent for twice-counted plots should be used. He pointed out that in taking a census of open woods with relatively small density of birds a higher percentage of the actual number of pairs will be observed than is possible in dense woods with a greater population.

Strip method

In applying the strip method, one or more transects are usually made through the area. These are usually straight lines and spaced evenly when more than one strip is used. A strip of definite width on each side of the line of travel is considered for the total width of strip, and all birds on this strip are counted.

Fisher (1939:10) used the strip method of King for taking a census of eastern ruffed grouse. He followed lines a quarter of a mile apart. All grouse, which were flushed, were recorded on a map of the area along with the distance from the observer to the point at which the grouse flushed. King's formula, which was used by Fisher for calculating the grouse population, was:

$$P = \frac{AZ}{XY}, \text{ where:}$$

P = the estimated total population of the area covered,

A = the total area of the tract,

Z = the total number of grouse observed along the strip,

X = the total distance walked by the observer,

Y = twice the average of the flushing distances to account for both sides of the line.

Dambach and Good (1940:64) used strips 50 to 150 feet wide in taking a bird census in fields and 75 feet in woodlots. Palmgren (1943:95) used a strip 40 meters wide in taking a census of woodlands.

Kendeigh (1944:77-78) reported obtaining indices of conspicuousness for various species. The average of these distances was used to represent one-half the width of strip. The inclusion of some birds beyond the average distance would be compensated by birds missed

at distances less than the average. Kendeigh wrote that a strip count through a forest probably would sample the population accurately because the area is nearly homogeneous, and the birds would be fairly uniformly spaced. Therefore, the number obtained for relative abundance may represent absolute abundance.

In an examination of the strip method of King, Hayne (1949:146-152) showed by example that using the average of the flushing distances of a pheasant population, in figuring the width of plot, resulted in a number of birds per acre which was much below the known population. Hayne suggested computing separately each class of bird, with respect to flushing distance. These numbers were added to represent the relative abundance of birds per acre. Using this method of computation, Hayne obtained a figure which was very close to the absolute abundance of birds for the area studied.

Small sample-plot method

The small sample-plot method is usually concerned with taking counts on plots of small size, with the plots being evenly spaced over the area for which the relative abundance of birds is desired. The results obtained from the small plots are projected over the entire area to arrive at a figure of the total population.

To sample all types of communities in proportion to their frequency of occurrence, Kendeigh (1944:95) suggested that plots be established at uniform intervals along lines which are uniform distances apart.

Plots 30 meters square were used by Twomey (1945:177) in taking a census of the bird population of an elm-maple forest. He selected plots far enough apart that the earlier activities on the preceding plot did not affect the birds on the plots still to be counted.

Quarter-acre plots, 120 feet in diameter, were used by Yeager (1955:149-150) to take a census of woodpeckers and mammals in green and beetle killed spruce-fir timber in Colorado. A period of 15 minutes was spent in the center of each plot. At the end of this time, Yeager positively identified all woodpeckers which had not been previously identified, except for a few which flew off the plot before the end of the 15 minute period.

A new method was used by Turcek (1949:5) to determine the bird population of forests in South Slovakia infested with gypsy moth larvae. The size of the plots were one hectare, which is approximately two and one-half acres. The birds were counted and expressed as birds per hectare per hour. When the census was repeated at various times of the day and in different

areas in the same biotic community, he believed a figure was arrived at which represented the absolute or nearly absolute population.

Contagious population

Work on the dispersal patterns of animals has been carried out largely with invertebrates, but the results seem to have general applicability to birds.

Cole (1946:70-83) analyzed statistically the dispersion pattern of some spiders, insects, isopods and diplopods. Only the spiders showed a random distribution, while the others were distributed in a contagious manner.

Cole (1946a:332) wrote that large groups of individuals are formed by favorable local conditions, inherent social tendencies, common origin, or local disrupting factors such as terrain. Elton (1949:6-9) stated that the interspersion and patterning of animal populations is partly due to terrain and vegetation. Animals also impose new dispersion patterns of their own making. The distribution of wide ranging species will vary between day and night. Thus population patterns have diurnal cycles upon which will be superimposed seasonal social activity as well as yearly fluctuations in density.

Blackford (1955:28) reported woodpeckers were attracted from a large portion of surrounding country to boring beetles. The beetles were making a mass attack on fire damaged or weakened trees in the Kootenai National Forest of Montana. This would give possible support to Cole's earlier statement concerning the contagiousness of a population due to response to favorable local conditions.

Summary

In taking a census of any species, it is necessary to consider the biological and environmental factors which affect the animals, and thus cause fluctuations in the counts. Adverse weather conditions tend to reduce the activity of birds and thus the number counted. The behavior and conspicuousness of birds vary with the season, partly due to the biological responses of the bird and partly due to the effect of environment.

Several methods of taking censuses of birds have been used. The fixed-plot method usually encompasses a large area, the exact size of which varies with the worker and the conditions under which the census is taken. It is especially useful in taking a census of breeding birds. The number of censuses necessary to count all the birds of an area during the nesting season is four or five.

The strip method of taking a census has been used for various birds. The width of strip has varied with the worker and conditions of weather, terrain, and plant communities. Several modifications of the strip method have been devised whereby the width of strip is determined by the flushing distances of the birds or is based on an index of conspicuousness for the species.

The small sample-plot method has been used in taking a census of forest birds. The size of plot has varied with the worker and the conditions of the census. By spacing the plots evenly along lines through an area, all communities are visited in proportion to their occurrence, giving a more accurate census of the area.

The dispersal patterns of animals must be considered in interpreting the results of the census. This is especially true when attempting to project the results of a census over an area larger than that used for the census. A contagious distribution is usually the result of a favorable environment, social tendencies, common origin, or the guiding effect of terrain.

Chapter III

METHODS AND MATERIALS

Data for the comparative study of methods for the census of woodpeckers were collected from October, 1956, through March, 1958. Three areas were chosen for the study, each of which had a different Engelmann spruce beetle infestation classification--epidemic, endemic, and past epidemic. These were located at Wolf Creek Pass, Hidden Valley, and Rabbit Ears Pass, respectively. Three methods for taking censuses, the fixed-plot method, one-acre method, and one-fourth-acre method, were used on each of the three areas. Two other methods, the average-distance method and strip method, were used only at Wolf Creek Pass. The three areas were visited several times during the period of study but not at regular intervals due to the distances involved. The study at Rabbit Ears Pass had to be terminated in October, 1957, due to the closing of US Highway 40 for the winter. Factors, such as weather and habitat, were investigated to determine their affect on the population of woodpeckers.

Fixed-plot method

In each of the three areas, a 20-acre plot was selected which would be typical of the Engelmann spruce

beetle infestation which that area was to represent. The plots were of different shapes due to irregularities in plant communities and topography (Fig's. 1, 2, 3). At Wolf Creek Pass, the plot was eight by 25 chains, one chain equaling 66 feet, with part of the plot offset to avoid a large meadow. The plot at Rabbit Ears Pass was six by 33.5 chains to avoid the highway on one side and a meadow on the opposite side. At Hidden Valley, a plot 10 by 20 chains was used to avoid a very steep area which would have been difficult to traverse on snowshoes.

The plots were established with the aid of a compass and a one-fourth-inch rope which was one chain in length and which had a stake tied to one end. The side boundaries of the plots were not marked, since the fixed-plot method of taking a census involved judging a distance of one chain on each side of the paths. The paths were located two chains apart and were marked so they could be followed easily during each succeeding census.

Trees were marked along the paths at each interval of one chain. This aided in taking censuses by the one-acre method, since it was easier to tally these marks to determine the length of one acre than to pace the distance each time a census was taken. At Wolf Creek Pass, an ax blaze was used to mark trees along the paths.

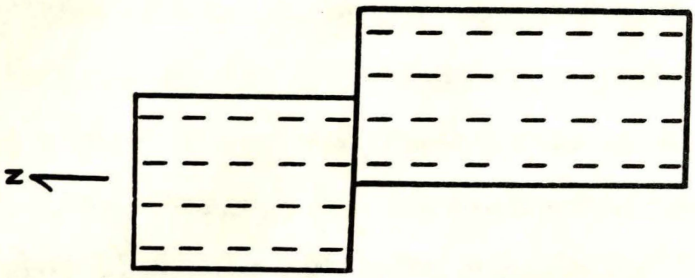

Fig. 1.--Twenty-acre plot at Wolf Creek Pass.

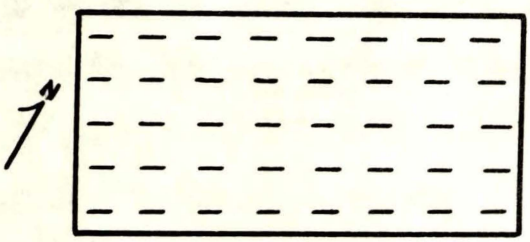

Fig. 2.--Twenty-acre plot at Hidden Valley.

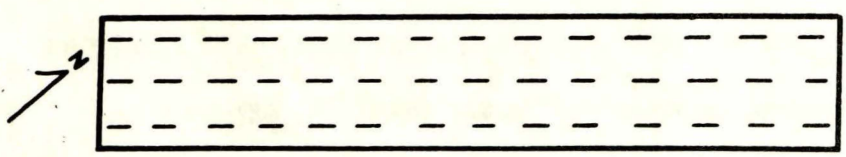

Fig. 3.--Twenty-acre plot at Rabbit Ears Pass.

Scale: 1/8 inch = 1 chain
Paths — —

The marks had to be made high on the trees, so that snow during the winter months would not obscure them and thus make the paths impossible to follow. The paths of the fixed plot at Rabbit Ears Pass were marked with yellow paint from a pressurized can. This method of marking did not work well due to cold temperatures which caused the paint to be too thick to spray as it should. A can of orange paint and a brush were used at Hidden Valley to mark the trees along the paths. This method was more successful than the other two, and the orange paint was more easily seen than the blazes used at Wolf Creek Pass or the yellow paint used at Rabbit Ears Pass.

In taking the fixed-plot census, the paths were followed and all woodpeckers for a distance of one chain on both sides of the path were counted. The plot was traversed slowly, and frequent stops were made to listen for the food tapping and digging of woodpeckers. It was necessary to leave the path to establish the identity of most birds. The amount of time used to take a census of the plot was dependent upon the number of birds present and upon weather conditions. During windy or snowy weather, the reduced distance at which birds could be heard made it necessary to stop more frequently while taking the census.

One-acre method

The one-acre method was used along the paths of the fixed plot at the same time that the fixed-plot method was used. The number of woodpeckers found to be present was summarized at the end of each of the 20 acres. Only 10 of the 20 acres were used for determining the number of woodpeckers present on the entire plot. In an effort to randomize the acres which would be used, a coin was tossed for each census. If the coin landed head up, every other acre starting with the first was used. If the coin landed tail up, every other acre starting with the second was used.

One-fourth-acre method

The one-fourth-acre method usually consisted of 10 samples taken on the fixed plot, each sample being a circular plot, 120 feet in diameter. The samples were evenly spaced along two of the paths of the 20-acre plot; the spacing of samples was determined by pacing. A specific period of time was spent in the center of each sample plot, except when it was necessary to move about within the plot to make positive identification of a bird before it could fly off the plot. The first period of time used was 15 minutes. This time period was then

shortened to 10 minutes and finally to five minutes. This shorter period of time was thought to give adequate time to count the birds which were present.

Average-distance method

The average-distance method was used along a road extending through the plot at Wolf Creek Pass and also along the paths of the plot. The distance at which the bird was located, at a right angle to the road or path, was determined by pacing. The average of these distances was doubled and used to represent the plot width. The length of the plot was represented by the distance walked.

Strip method

The strip method was conducted along the paths of the fixed plot at Wolf Creek Pass. The width of strip was 33 feet on both sides of the path, with all woodpeckers within the strip being counted.

Simultaneous counts

The fixed-plot method, average-distance method, and strip method were used simultaneously along the paths of the fixed plot. This procedure eliminated variability due to days, time of day, weather conditions, and

behavior of the woodpeckers. This made it possible to make a more reliable comparison of methods, since all variability was due to the analytical procedures employed for each method.

Weather data

The temperature was taken morning, noon and evening with a Fahrenheit thermometer. The temperature for any hour in between was interpolated. The relative humidity was determined by using a sling psychrometer. One difficulty encountered in using the psychrometer, and one which prevented its use during the winter months, was the low termperatures found in the three areas under study. The thermometers of the psychrometer registered no lower than a plus 20°F., while temperatures in these areas fell as low as a minus five degrees Fahrenheit. The sky cover was recorded, and an estimate was made of the wind velocity.

Habitat sample

A five percent habitat sample was taken of each plot to determine the numbers and sizes of living, dead, and infested trees of each species. Ten one-tenth-acre samples were taken along two of the paths of each 20-acre plot. The samples were evenly spaced; the distance was

determined by pacing. A one-fourth-inch rope, one chain in length, was used to determine a one-tenth-acre square. The square was then surrounded by cotton twine. The diameter, at breast height, of all trees five inches in diameter and over was obtained with a diameter tape.

Special equipment

Special mimeographed sheets were used in recording census data. An 8x26 binocular and the handbook, "A Field Guide to Western Birds", by Peterson, were used in identifying birds. During the late fall, winter and early spring, snowshoes were a necessity in order to traverse the deep snow.

Chapter IV

ANALYSIS OF DATA

The data collected during this study were subjected to various analyses and comparisons to determine the differences which existed between methods used in taking censuses. Factors were analyzed to determine the causes for fluctuations in counts of woodpeckers.

In making the statistical analysis of results obtained by various methods, analysis of variance was most useful. The Poisson distribution and negative binomial distribution were employed to analyze the distribution of woodpeckers. The Poisson is concerned with random distribution, while the negative binomial (Bliss and Fisher, 1953) is a contagious distribution. Regression and correlation were used to relate the number of woodpeckers to the number of infested Engelmann spruce.

Analysis of habitat

Ten one-tenth-acre habitat samples were taken on each 20-acre plot to determine the species and sizes of trees present. The trees were recorded according to diameter in inches at breast height (D. B. H.) and whether living, dead, or infested with primary bark

beetles. Primary bark beetles are those beetles which make the initial attack on a living tree. These data are presented in Tables 1, 2 and 3 of Appendix A.

The stand at Wolf Creek Pass was predominately Engelmann spruce with only 7.8 percent sub-alpine fir. The sample of trees revealed that 72.2 percent were living Engelmann spruce, 15.8 percent were dead Engelmann spruce, and 4.2 percent were Engelmann spruce infested with the Engelmann spruce beetle. The sub-alpine fir in the sample were all living trees.

The sample taken on the plot at Hidden Valley gave the following percentages: 46.1 Engelmann spruce, 29.5 sub-alpine fir, 19.4 lodgepole pine, and 5 limber pine. The sample of trees showed 43.4 percent to be living Engelmann spruce, 2.7 percent dead Engelmann spruce, with none of the spruce being infested. Of the 29.5 percent sub-alpine fir, 18.1 percent were living trees, 11.4 percent were dead trees, and none were infested with primary bark beetles. The sample revealed that 15.4 percent of the trees were living lodgepole pine, 4 percent were dead lodgepole pine, with none being infested. The sample of limber pine was all living trees.

The sample taken at Rabbit Ears Pass consisted of 42.7 percent Engelmann spruce, 33.8 percent sub-alpine

fir, and 23.5 percent lodgepole pine. The sample revealed 25.6 percent dead Engelmann spruce as compared to 17.1 percent living Engelmann spruce. None of the spruce trees were infested with the Engelmann spruce beetle. Of the total number of trees, 32.5 percent were living sub-alpine fir, 1.3 percent were dead sub-alpine fir, with none of the fir being infested with primary bark beetles. The sample showed that 18.8 percent of the trees were living lodgepole pine, 4.7 percent were dead lodgepole pine, and none of the pine were infested with primary bark beetles.

It should be noted that only at Wolf Creek Pass was a large number of trees present infested with primary bark beetles. Wolf Creek Pass and Hidden Valley had approximately the same percentage of dead trees with 15.8 and 14.8, respectively. At Rabbit Ears Pass, 31.6 percent of the trees recorded in the sample were dead.

Other birds were found to be present on the plots in addition to the three species of woodpeckers being studied. The birds were observed in order to determine their association with the woodpeckers.

Other birds found to be present on the three plots during the fall and winter months were the White-breasted Nuthatch, Sitta carolinensis; Red-breasted

Nuthatch, Sitta canadensis; Brown Creeper, Certhia familiaris; Golden-crowned Kinglet, Regulus satrapa; Mountain Chickadee, Parus gambeli; Gray-headed Junco, Junco caniceps; Oregon Junco, Junco oreganus; Gray Jay, Perisoreus canadensis; Clark's Nutcracker, Nucifraga columbiana; and the Common Raven, Corvus corax.

Birds found on the plots during the spring and summer months, in addition to the afore-mentioned, were the Red-shafted Flicker, Colaptes cafer; Violet-green Swallow, Tachycineta thalassina; Robin, Turdus migratorius; Hermit Thrush, Hylocichla guttata; Townsend's Solitaire, Myadestes Townsendi; Ruby-crowned Kinglet, Regulus calendula; Audubon's Warbler, Dendroica auduboni; Wilson's Warbler, Wilsonia pusilla; Western Tanager, Piranga ludoviciana; Pine Grosbeak, Pinicola enucleator; Rough-legged Hawk, Buteo lagopus; Goshawk, Accipiter gentilis; and the Sparrow Hawk, Falco sparverius.

Fixed-plot method

Each plot used for the fixed-plot method consisted of 20 acres with marked paths, 132 feet apart, traversing it. The route for taking the census followed the paths, and woodpeckers were counted for a distance of one chain (66 feet) on each side of the path.

Wolf Creek Pass.--A total of 18 censuses was taken at Wolf Creek Pass by the fixed-plot method from November, 1956, through March, 1958. This method showed that the number of woodpeckers per acre decreased from a high of 1.35 in November, 1956, to 0.08 in June, 1957. From June, 1957, to December, 1957, the number of woodpeckers per acre varied from 0.05 to 0.33. This number increased to 0.60 woodpeckers per acre in March of 1958. Each census using the fixed-plot method showed at least one woodpecker to be present on the 20-acre plot (Table 1, Fig. 4).

Hidden Valley.--Seven censuses were taken on the fixed-plot at Hidden Valley between the dates of February 16, 1957, and February 24, 1958. The greatest number of woodpeckers per acre was 0.20, which was recorded on April 20, 1957. Two censuses by this method failed to reveal the presence of woodpeckers (Table 2, Fig. 5).

Rabbit Ears Pass.--Seven censuses were taken by the fixed-plot method at Rabbit Ears Pass from December, 1956, to October, 1957. The only woodpeckers recorded were one unidentified on December 17, and one on June 28 (Table 3, Fig. 6).

It should be pointed out that a large percentage of the woodpeckers recorded at Hidden Valley and

Table 1.--NUMBERS OF WOODPECKERS AS SHOWN BY THE FIXED-PLOT METHOD AT WOLF CREEK PASS.

Date	Hairy	Three-toed	Downy	Unidentified	Total	Number per acre
11-26-56	6	8	8	5	27	1.35
4-26-57	8	7	0	1	16	0.80
4-27-57	6	5	0	3	14	0.70
6-21-57	0	1	0	0	1	0.08*
6-22-57	0	1	0	1	2	0.10
8-15-57	0	1	0	1	2	0.10
8-15-57	0	4	0	0	4	0.33*
8-28-57	0	1	0	0	1	0.08*
9-9-57	0	2	0	0	2	0.17*
9-27-57	0	1	0	0	1	0.05
9-27-57	2	1	0	0	3	0.15
9-28-57	0	3	0	2	5	0.25
10-11-57	0	1	0	0	1	0.05
10-12-57	0	5	0	0	5	0.25
12-17-57	0	0	0	1	1	0.05
12-18-57	0	1	0	1	2	0.10
12-19-57	1	2	1	0	4	0.20
3-18-58	1	10	1	0	12	0.60
TOTALS	24	54	10	15	103	5.41
MEANS	1.33	3.00	0.56	0.83	5.72	0.30

*Only 12 acres censused.

Table 2.--NUMBERS OF WOODPECKERS AS SHOWN BY THE FIXED-PLOT METHOD AT HIDDEN VALLEY.

Date	Hairy	Three-toed	Downy	Unident-ified	Total	Number per acre
2-16-57	0	1	0	0	1	0.05
4-6-57	0	0	0	1	1	0.05
4-20-57	1	0	0	3	4	0.20
7-20-57	0	0	0	0	0	0.00
9-7-57	0	1	0	0	1	0.05
10-29-57	0	0	0	0	0	0.00
2-24-58	2	0	0	0	2	0.10
TOTALS	3	2	0	4	9	0.45
MEANS	0.43	0.29	0.00	0.57	1.29	0.06

Table 3.--NUMBERS OF WOODPECKERS AS SHOWN BY THE FIXED-PLOT METHOD AT RABBIT EARS PASS.

Date	Hairy	Three-toed	Downy	Unident-ified	Total	Number per acre
12-17-56	0	0	0	1	1	0.05
12-18-56	0	0	0	0	0	0.00
6-27-57	0	0	0	0	0	0.00
6-28-57	0	0	0	1	1	0.05
8-24-57	0	0	0	0	0	0.00
9-22-57	0	0	0	0	0	0.00
10-5-57	0	0	0	0	0	0.00
TOTALS	0	0	0	2	2	0.10
MEANS	0.00	0.00	0.00	0.29	0.29	0.01

Rabbit Ears Pass was unidentified. In these areas, the birds tended to move rapidly from tree to tree making identification difficult.

One-acre method

The one-acre method was used at the same time as the fixed-plot method. As the fixed-plot censuses were taken, the counts were summarized at the end of each five chains, thereby separating the data into one-acre counts. Since only half of the 20-acre plot was used in computing the number of birds per acre, a coin was tossed in order to select at random the one-acre counts which would be used.

Wolf Creek Pass.--The results of this method revealed a high of 1.50 woodpeckers per acre on November 26, 1956, then a decline to zero in June, 1957. A high of 0.67 was reached during the summer on August 15, 1957. From August through December the number of woodpeckers per acre varied from zero to 0.30 for the various counts taken. In March, 1958, 0.18 woodpeckers per acre were recorded. Four censuses by this method showed no woodpeckers to be present (Table 4, Fig. 4). Zero counts did not occur while using the fixed-plot method.

Hidden Valley.--The one-acre method gave a high of 0.20 woodpeckers per acre on April 20, 1957, which was

Table 4.--NUMBERS OF WOODPECKERS AS SHOWN BY THE ONE-ACRE METHOD AT WOLF CREEK PASS.

Date	Hairy	Three-toed	Downy	Unidentified	Total	Number per acre
11-26-56	3	4	4	4	15	1.50
4-26-57	4	6	0	1	11	1.10
4-27-57	3	5	0	2	10	1.00
6-21-57	0	0	0	0	0	0.00*
6-22-57	0	0	0	1	1	0.10
8-15-57	0	1	0	1	2	0.20
8-15-57	0	4	0	0	4	0.67*
8-28-57	0	0	0	0	0	0.00*
9-9-57	0	1	0	0	1	0.17*
9-27-57	0	0	0	0	0	0.00
9-27-57	1	1	0	0	2	0.20
9-28-57	0	0	0	1	1	0.10
10-11-57	0	0	0	0	0	0.00
10-12-57	0	3	0	0	3	0.30
12-17-57	0	0	0	1	1	0.10
12-18-57	0	0	0	1	1	0.10
12-19-57	0	1	1	0	2	0.20
3-18-58	0	3	0	0	3	0.30
TOTALS	11	29	5	12	57	6.04
MEANS	0.61	1.61	0.28	0.67	3.17	0.34

*Only 6 acres censused.

the same as for the fixed-plot method. Only two censuses by this method failed to reveal woodpeckers to be present (Table 5, Fig. 5). Likewise, two censuses while using the fixed-plot method failed to reveal woodpeckers.

Rabbit Ears Pass.--The one-acre method showed no woodpeckers to be present at Rabbit Ears Pass. There was actually one bird recorded on two different days while using the fixed-plot method.

One-fourth-acre method

The one-fourth-acre method was conducted along two of the paths of the fixed plot. The one-fourth-acre samples were evenly spaced along the paths, the distance being determined by pacing. Each one-fourth acre was a circular plot, 120 feet in diameter. One census by this method usually consisted of ten samples, however several included 20 samples.

Twenty samples were taken at Wolf Creek Pass on March 19, 1958, with fifteen minutes being spent on each plot. The 15 minute period was divided into five minute periods. It was found that all woodpeckers were recorded during the first five minutes, with no new arrivals during the second and third five minute periods.

Wolf Creek Pass.--Fifteen censuses were taken by the one-fourth-acre method at Wolf Creek Pass between

Table 5.--NUMBERS OF WOODPECKERS AS SHOWN BY THE ONE-ACRE METHOD AT HIDDEN VALLEY.

Date	Hairy	Three-toed	Downy	Unidentified	Total	Number per acre
2-16-57	0	1	0	0	1	0.10
4-6-57	0	0	0	1	1	0.10
4-20-57	1	0	0	1	2	0.20
7-20-57	0	0	0	0	0	0.00
9-7-57	0	1	0	0	1	0.10
10-29-57	0	0	0	0	0	0.00
2-24-58	1	0	0	0	1	0.10
TOTALS	2	2	0	2	6	0.60
MEANS	0.29	0.29	0.00	0.29	0.86	0.09

the dates of October 6, 1956, and March 19, 1958. The greatest number of woodpeckers per acre recorded by this method was 4.00, on November 24, 1956. The number of woodpeckers then decreased to 0.33 by June, 1957, according to the one-fourth-acre method. In September of 1957, 0.80 woodpeckers per acre were recorded, and in December, 1.20 birds per acre were recorded. The one-fourth-acre method revealed 0.80 woodpeckers per acre to be present in March, 1958 (Table 6, Fig. 4).

Of the 15 censuses taken at Wolf Creek Pass, while using the one-fourth-acre method, seven were zero counts. Those counts showing birds to be present were nearly always higher than those obtained by other methods.

Hidden Valley.--The one-fourth-acre method was used twice at Hidden Valley, once on April 20, 1957, and once on February 24, 1958. No woodpeckers were recorded either time, while both the fixed-plot method and the one-acre method revealed woodpeckers to be present on these dates.

Rabbit Ears Pass.--Three censuses were conducted at Rabbit Ears Pass, while using the one-fourth-acre method, with no woodpeckers being recorded. However, the fixed-plot method showed a woodpecker to be present on two of the dates on which the one-fourth-acre method was used, December 17, 1956, and June 28, 1957.

Table 6.--NUMBERS OF WOODPECKERS AS SHOWN BY THE ONE-FOURTH-ACRE METHOD AT WOLF CREEK PASS.

Date	Hairy	Three-toed	Downy	Unident-ified	Total	Number per acre
10-6-56	3	1	0	1	5	2.00
11-24-56	4	0	4	2	10	4.00
4-25-57	1	0	0	1	2	0.57
4-27-57	3	0	0	0	3	1.20
6-23-57	0	0	0	1	1	0.33
8-15-57	0	0	0	0	0	0.00
9-10-57	0	2	0	0	2	0.80
9-27-57	0	0	0	0	0	0.00
10-11-57	0	0	0	0	0	0.00
10-12-57	0	0	0	0	0	0.00
12-17-57	0	0	0	0	0	0.00
12-18-57	0	3	0	0	3	1.20
12-19-57	0	0	0	0	0	0.00
12-20-57	0	0	0	0	0	0.00
3-19-58	1	3	0	0	4	0.80
TOTALS	12	9	4	5	30	10.90
MEANS	0.80	0.60	0.27	0.33	2.00	0.73

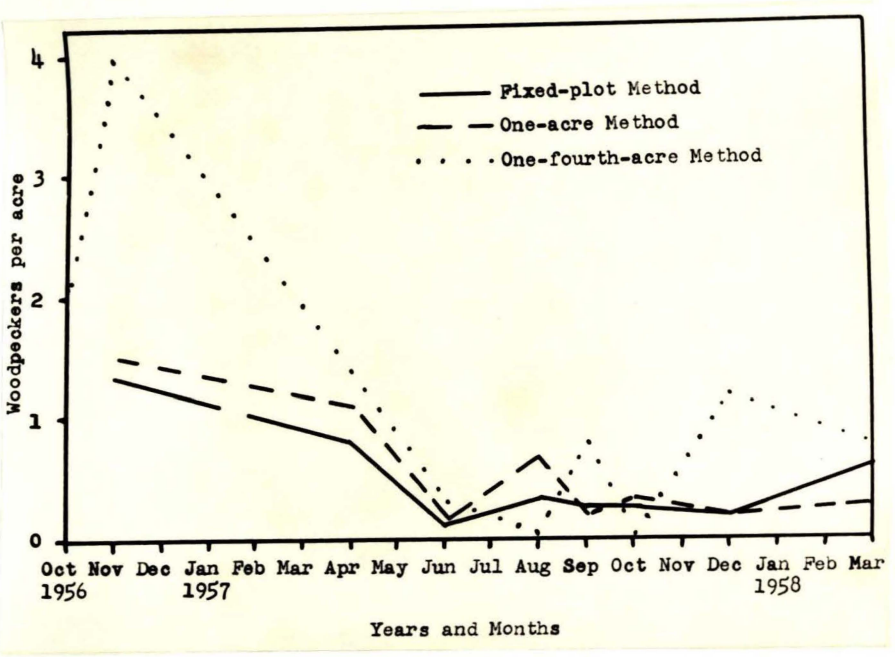

Fig. 4.--Numbers of woodpeckers recorded by three methods at Wolf Creek Pass.

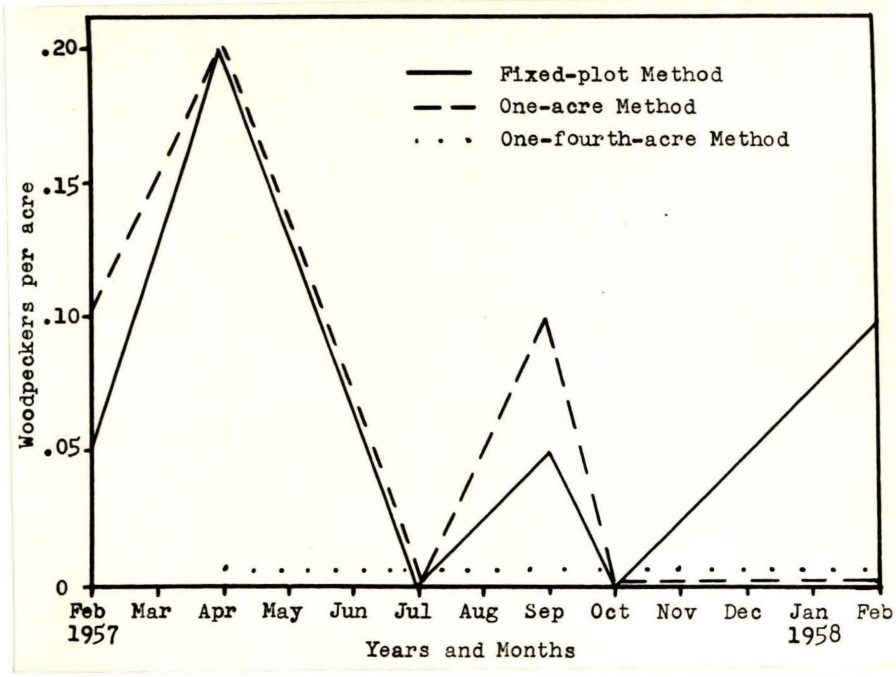

Fig. 5.--Numbers of woodpeckers recorded by three methods at Hidden Valley.

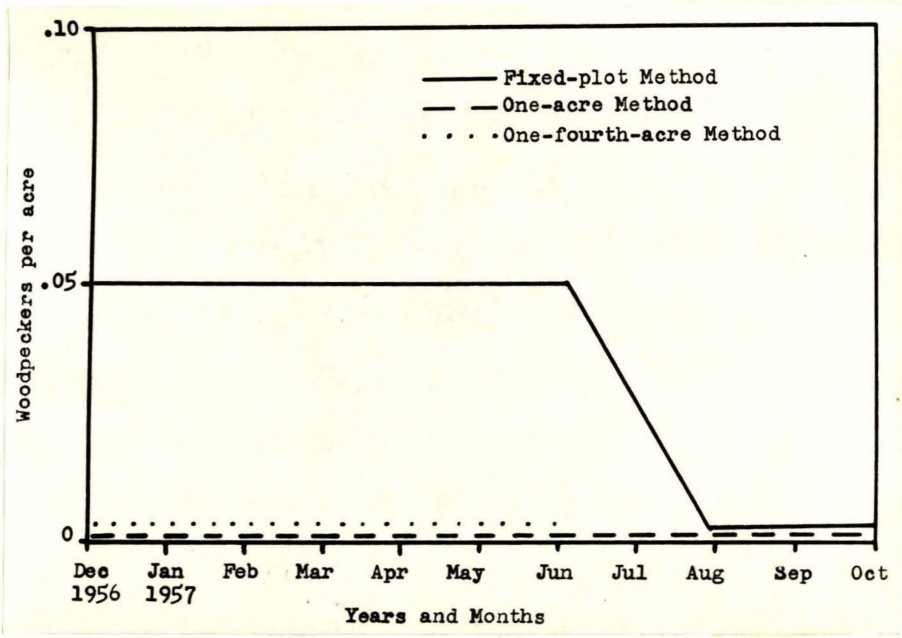

Fig. 6.--Numbers of woodpeckers recorded by three methods at Rabbit Ears Pass.

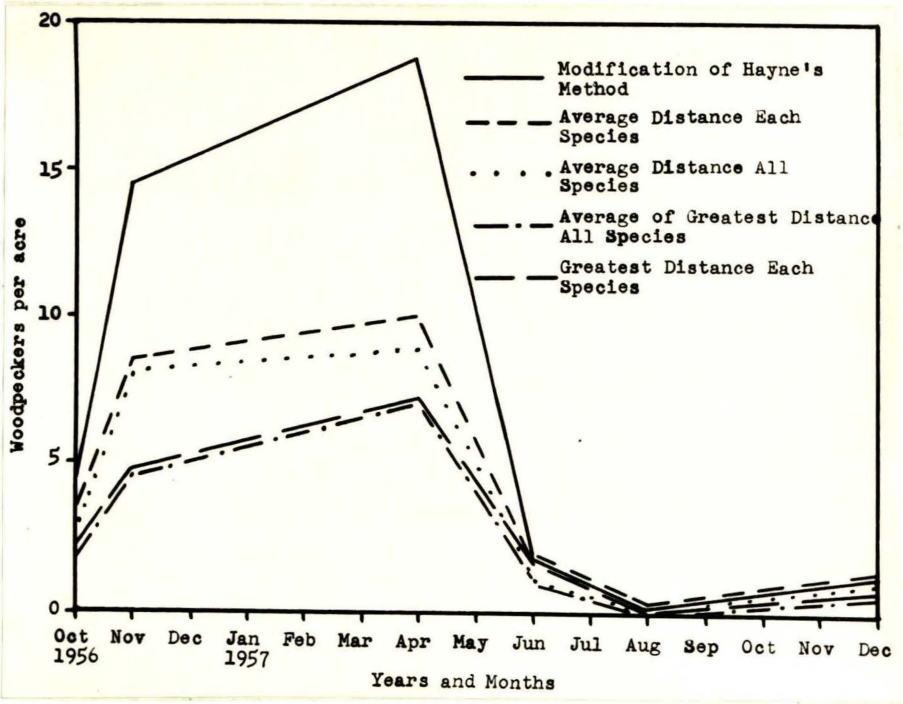

Fig. 7.--Numbers of woodpeckers computed by five methods from data of average-distance method at Wolf Creek Pass.

Comparison of three methods

The fixed-plot method, one-acre method, and one-fourth-acre method were compared on the basis of numbers of birds per acre and numbers of birds per acre per hour recorded during the use of the methods.

Wolf Creek Pass was the only area to yield enough counts with woodpeckers by all three methods for a comparison to be made. The average for all censuses taken by the fixed-plot method was 0.30 woodpeckers per acre. The average numbers of woodpeckers per acre recorded by the one-acre and one-fourth-acre methods were 0.34 and 0.73, respectively.

An analysis of variance was made to determine if a significant difference existed between the numbers of birds per acre recorded during the use of each method. To avoid the reducing effect that a zero count would have, days were selected when all methods revealed woodpeckers to be present. If all methods were not used on the same day, counts taken on the day preceding or following were used. The numbers of birds per acre recorded by each method did not differ significantly at the five percent level (Table 7).

The number of birds per acre per hour was computed for each census by multiplying the total number of

acres upon which the census was made by the total number of hours spent in taking the census. The resulting figure was then divided into the total number of birds, yielding the number of birds per acre per hour. When working with a series of censuses, raw data from two or more censuses will, when combined, give a smaller value, since a geometric increase in the divisor is obtained by multiplying the acres by the hours, while only an arithmetic (additive) increase in the dividend is obtained when the birds for several censuses are added together. This value is much smaller for birds per acre per hour than is the case when the number of birds per acre per hour is figured separately for each individual census.

The average number of birds per acre per hour was 0.16 for the fixed-plot censuses, 0.29 for the one-acre censuses, and 0.29 for the one-fourth-acre censuses (Tables 1, 2, 3, Appendix B). An analysis of variance was made to determine if the number of birds per acre per hour obtained by the use of each method differed significantly. Days were selected when all methods showed a count of woodpeckers, or if all methods had not been used the same day, the day preceding or following was used. No significant difference was observed between methods or between days at the five percent level, with respect to

Table 7.--ANALYSIS OF VARIANCE OF BIRDS PER ACRE RECORDED BY THE FIXED-PLOT METHOD, ONE-ACRE METHOD, AND ONE-FOURTH-ACRE METHOD.

Source of variation	Degrees of freedom	Means of squares	Observed F
Methods	2	1.1525	3.29
Days	5	1.7351	4.95*
Error	10	0.3504	

* Significant at 5 percent level.

Table 8.--ANALYSIS OF VARIANCE OF BIRDS PER ACRE PER HOUR RECORDED BY THE FIXED-PLOT METHOD, ONE-ACRE METHOD, AND ONE-FOURTH-ACRE METHOD.

Source of variation	Degrees of freedom	Means of squares	Observed F
Methods	2	0.1978	2.57
Days	6	0.1548	2.01
Error	12	0.0770	

the number of woodpeckers per acre per hour computed from the censuses (Table 8).

Average-distance method

The average-distance method was used only at Wolf Creek Pass. The censuses were taken along a road 0.2 mile long. The road passed through the plot in the area of greatest concentration of woodpeckers, hence the results obtained from these censuses cannot be compared with those of the other three methods. The census route followed the road. All woodpeckers heard on both sides of the road were located and identified, and the distance at a right angle from the road to the bird was determined by pacing. The average of the distances was used for one-half the plot width. This figure was then doubled to account for both sides of the road. The numbers of birds per acre were computed from these figures and appear in Table 9 and Figure 7.

Four other methods were used to compute the number of woodpeckers per acre using the data obtained by the average-distance method. The results of the methods of computation appear in Table 9 and Figure 7 and were used on a comparative basis.

Hayne (1949:146-152) used a method whereby the distance from the census taker at which a pheasant was

observed to flush was used as one-half the plot width in computing the number of birds per acre. This was done for each distance and group of birds observed at that distance. The figures derived in this manner were added to give the total number of birds per acre. A modification of this method was used in computing the number of woodpeckers per acre in which the distance at a right angle from the route of census to the bird was used instead of the flushing distance.

Another method applied to the average-distance data was the average distance that each species was observed. This distance, obtained for each species, was used for one-half the plot width in computing the number of that species per acre. The figures for the three species were added to give the total number of woodpeckers per acre.

A method using the greatest distance each species was heard was used for one-half the plot width in computing the number of that species per acre. These figures were added to give the total number of woodpeckers per acre.

A modification of the last method mentioned was used whereby the greatest distance for each species was added and averaged. This figure was used for one-half

the plot width for computing the number of woodpeckers per acre for all species.

Upon examining some of the numbers of woodpeckers arrived at by these methods, the modification of the method used by Hayne shows the highest figures. On October 6, 1956, this method gave a figure of 2.01 woodpeckers per acre. A high of 18.81 birds per acre was computed for April 27, 1957, and the average for the 22 censuses was 5.01 woodpeckers per acre.

The method using the average distance of each species gave a figure of 1.81 woodpeckers per acre for October 6, and 10.01 birds per acre on April 26. The average for all censuses using this method of computation was 3.13 woodpeckers per acre.

The method using the average distance of all species gave a figure of 1.43 woodpeckers per acre for October 6, 1956. On April 26, 1957, a high of 8.93 birds per acre was shown to be present, and the average of all censuses by the average-distance method was 2.84 woodpeckers per acre.

The method using the greatest distance at which each species was observed revealed 1.10 woodpeckers per acre to be present on October 6. The greatest number of woodpeckers per acre computed by this method was 7.26 for April 27, and the average for all censuses was 2.07.

Table 9.--NUMBERS OF WOODPECKERS PER ACRE COMPUTED BY FIVE METHODS USING DATA OF AVERAGE-DISTANCE METHOD.

Date	Modification of Hayne's method	Average distance separately	Average distance	Greatest distance separately	Average of greatest distance
10-6-56	2.01	1.81	1.43	1.10	0.90
10-6-56	1.19	1.07	0.74	0.86	0.88
10-6-56	1.99	1.59	1.54	1.23	1.24
10-6-56	4.12	3.59	2.78	2.10	1.95
11-24-56	13.86	8.62	8.07	4.81	4.79
11-24-56	14.61	7.24	5.79	3.64	2.67
11-26-56	5.98	4.20	4.12	2.76	2.84
4-25-57	3.16	2.29	2.19	1.51	1.59
4-26-57	11.15	10.01	8.93	5.87	7.04
4-27-57	16.76	7.10	6.67	4.10	3.78
4-27-57	18.81	7.90	7.77	7.26	4.13
4-27-57	11.63	8.76	8.29	6.14	6.64
6-22-57	1.78	1.78	1.26	1.78	1.27
6-23-57	0.34	0.34	0.34	0.34	0.34
8-15-57	0.00	0.00	0.00	0.00	0.00
8-15-57	0.00	0.00	0.00	0.00	0.00
12-17-57	0.00	0.00	0.00	0.00	0.00
12-17-57	0.00	0.00	0.00	0.00	0.00
12-17-57	0.00	0.00	0.00	0.00	0.00
12-18-57	1.17	0.97	0.97	0.75	0.75
12-18-57	0.53	0.52	0.52	0.46	0.46
12-19-57	1.14	1.06	1.06	0.83	0.83
TOTALS	110.23	68.85	62.47	45.54	42.10
MEANS	5.01	3.13	2.84	2.07	1.91

L.S.D., 95 percent level = 0.16

Using the greatest distance of each species and averaging the distances for one-half the plot width gave a figure of 0.90 woodpeckers per acre for October 6. This method showed a high of 7.04 birds per acre on April 26, and an average of 1.91 for all censuses.

An analysis of variance was made to determine if a significant difference existed between the numbers of woodpeckers per acre computed by the five methods. Significance was observed at the one percent level between methods and between days (Table 10). The least significant difference of 0.16 was the maximum allowable difference between means before significance between any two methods could be obtained. The methods--modification of Hayne's, average distance of each species, and average distance of all species--gave numbers of birds per acre which were significantly different from one another. These methods gave numbers of birds per acre which were significantly larger than those derived by the method using the greatest distance of each species and the method using the average of the greatest distance of each species. The latter two did not differ significantly from one another.

Table 10.--ANALYSIS OF VARIANCE OF NUMBERS OF WOODPECKERS OBTAINED BY FIVE METHODS OF COMPUTATION USING DATA OF AVERAGE-DISTANCE METHOD.

Source of variation	Degrees of freedom	Means of squares	Observed F
Methods	4	33.711	9.56**
Days	21	56.740	16.09**
Error	84	3.530	

** Significant at 1 percent level.

Table 11.--NUMBERS OF WOODPECKERS OBTAINED BY SEVEN METHODS AT WOLF CREEK PASS.

Date	Fixed plot	Strip method	Method of Hayne	Average distance each species	Average distance all species	Greatest distance each species	Average of greatest distance
10-11-57	0.05	0.00	0.066	0.066	0.066	0.066	0.066
10-12-57	0.25	0.20	0.463	0.306	0.306	0.165	0.165
12-18-57	0.10	0.10	0.275	0.275	0.176	0.110	0.176
12-19-57	0.20	0.30	0.933	0.538	0.330	0.132	0.256
3-18-58	0.60	0.80	2.232	1.329	1.329	0.600	0.600
TOTALS	1.20	1.40	3.969	2.514	2.207	1.073	1.263
MEANS	0.24	0.28	0.794	0.503	0.441	0.215	0.253

L. S. D., 95 percent level = 0.40.

Simultaneous count using fixed-plot method, strip method, and average-distance method

The fixed-plot, strip, and average-distance methods were used at the same time along the paths of the 20-acre plot. The data for the average-distance method were used to compute the woodpeckers per acre several different ways, as described previously on pages 56-57. The results of these censuses appear in Table 11.

An analysis of variance was made to determine if a significant difference existed between the numbers of birds per acre obtained by each method. A difference was observed at the five percent level (Table 12). The least significant difference was 0.40. This revealed that the modification of the method used by Hayne, with a mean of 0.79, gave numbers of birds per acre which were significantly larger than those for all other methods, except the method using the average distance of each species and the method using the average distance of all species. The methods--average distance of each species with a mean of 0.50, average distance of all species with a mean of 0.44, fixed-plot with a mean of 0.24, strip with a mean of 0.28, average of greatest distance of each species with a mean of 0.25, and greatest distance of each species with a mean of 0.22--gave numbers of

Table 12.--ANALYSIS OF VARIANCE OF NUMBERS OF WOODPECKERS PER ACRE OBTAINED BY SEVEN METHODS AT WOLF CREEK PASS.

Source of variation	Degrees of freedom	Means of squares	Observed F
Methods	6	0.2189	3.59*
Days	4	1.1162	18.33**
Error	24	0.0609	

* Significant at 5 percent level.

** Significant at 1 percent level.

Table 13.--NUMBERS OF TREES WITH NEST HOLES FOR EACH 20-ACRE PLOT.

	Wolf Creek Pass	Hidden Valley	Rabbit Ears Pass
Trees with nest holes	23.00	16.00	15.00
Trees with nest holes per acre	1.15	0.80	0.75
Trees with nest holes per woodpecker, average of all fixed-plot censuses	4.29	12.40	52.10
Trees with nest holes per woodpecker during greatest concentration of woodpeckers	0.852	4.00	15.00

woodpeckers per acre which did not differ significantly from one another.

Effect of trees with nest holes

The number of trees with nest holes in them, found to be present on each plot, was counted and the number per acre and the number per bird were computed (Table 13). All holes found in the trees were recorded as nest holes although it is recognized that not all were made or used for this purpose. Many of the holes were used as roosting sites and some were probably used for protection under adverse environmental conditions.

Wolf Creek Pass.--The number of trees with nest holes found on the 20-acre plot at Wolf Creek Pass was 23. This revealed that there were 1.15 trees per acre containing nest cavities and 4.29 such trees per bird, when using the average number of woodpeckers recorded during the use of the fixed-plot method. During the time of greatest concentration of birds this amounted to 0.85 cavity-containing tree per bird.

Hidden Valley.--Sixteen trees with nest holes were counted on the plot at Hidden Valley. This gave 0.80 tree per acre. Using the average number of woodpeckers recorded by the fixed-plot method, a figure of

12.40 trees per woodpecker was arrived at. At the time of greatest concentration of woodpeckers, there were 4.00 trees with nest holes per bird.

Rabbit Ears Pass.--The count of trees with nest holes on the 20-acre plot at Rabbit Ears Pass gave a figure of 15, or 0.75 tree per acre. The average number of woodpeckers for all fixed-plot censuses revealed that there were 52.10 such trees per bird, and at the time of greatest concentration of woodpeckers, there were 15 trees with nest holes per bird. Only at one time were more woodpeckers present on a plot than were there trees with nest holes. This was on November 11, 1956, at Wolf Creek Pass with 0.85 tree per bird.

Woodpeckers at Wolf Creek Pass were observed to fly into the plot in the morning. In the evening some were observed to leave. One of the latter was followed on April 27, 1957, and was observed to enter a cavity several hundred yards from the plot.

Seasonal variation

A count taken during only one season of the year could give a false impression as to the number of woodpeckers using an area, if the count was used to represent the number of woodpeckers present for the

entire year. Censuses were taken during several months of the year to determine if any variation in the population of woodpeckers occurred with respect to season.

Wolf Creek Pass.--The greatest number of woodpeckers per acre at Wolf Creek Pass, according to the fixed-plot method, was seen in November, 1956, when 1.35 were recorded. This number dropped to 0.80 by April, 1957, and to 0.10 by June. The number of woodpeckers then varied from 0.05 to 0.33 from June to December, 1957. The population then rose to 0.60 woodpeckers per acre in March, 1958 (Fig. 4).

Upon investigating the numbers per acre of each species of woodpecker, it was noted that the number of downys decreased from 0.40 in November, 1956, to zero in April, 1957. The number of hairys decreased from 0.40 in November, 1956, to 0.35 in April, 1957, while the number of three-toed woodpeckers increased from 0.30 to 0.40 between November and April. By June, the number of hairys dropped to zero, which left only 0.05 three-toed woodpeckers per acre on the plot. In August, there was an increase of three-toed woodpeckers and in September an increase in hairys (Fig. 8). It is recognized, where several months elapse between counts, as between November, 1956, and April, 1957, that the lines of the figures may

not represent the true population trends. It is not known if the population curve actually took this course or reached a higher peak sometime in between those dates.

The percentages of the population for each species show that 52.5 percent of the October, 1956, population were hairys. This dropped to 39.1 percent in November, 1956, then rose to 48.8 percent in April and dropped to zero in June, 1957. In October, 1956, 15.8 percent of the population were downys. This number rose to 32.8 percent in November, then dropped to 1.2 percent by April, 1957, and to zero in June. The percent of three-toed woodpeckers were 31.6 in October, 1956. This figure dropped to 28.1 percent in November, then rose to 50.0 percent in April, 1957. By June, 1957, three-toed woodpeckers constituted 100 percent of the population on the plot at Wolf Creek Pass. Three-toed woodpeckers were the only woodpeckers found on the plot during the summer months. In the latter part of September, 1957, 27.3 percent of the population were hairys. The number of hairys then dropped to zero in October, 1957. In December, 1957, the hairys constituted six percent of the population and in March, 1958, seven percent of the population. No downys were seen after April, until December, 1957, when six percent of the population were downys. In March,

Table 14.--PERCENTAGES OF EACH SPECIES OF WOODPECKER AT WOLF CREEK PASS.

Year	Month	Total number woodpeckers seen	Percent Hairys	Percent Downys	Percent Three-toed woodpeckers
1956	October	19	52.60	15.80	31.60
	November	64	39.10	32.80	28.10
1957	April	86	48.80	1.20	50.00
	June	5	0.00	0.00	100.00
	August	5	0.00	0.00	100.00
	September	11	27.30	0.00	72.70
	October	5	0.00	0.00	100.00
	December	16	6.25	6.25	87.50
1958	March	14	7.15	7.15	85.70

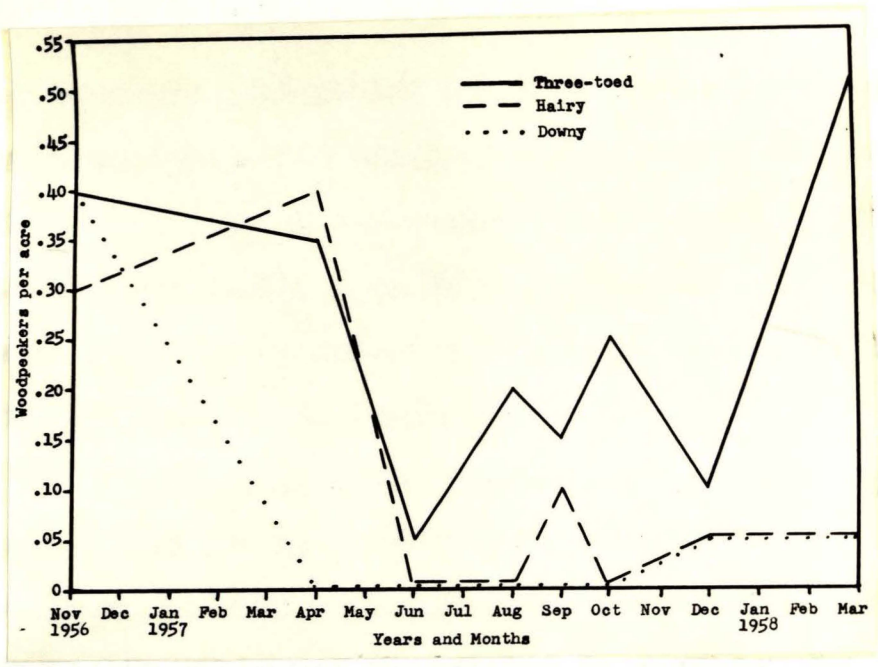

Fig. 8.--Numbers of each species of woodpecker at Wolf Creek Pass.

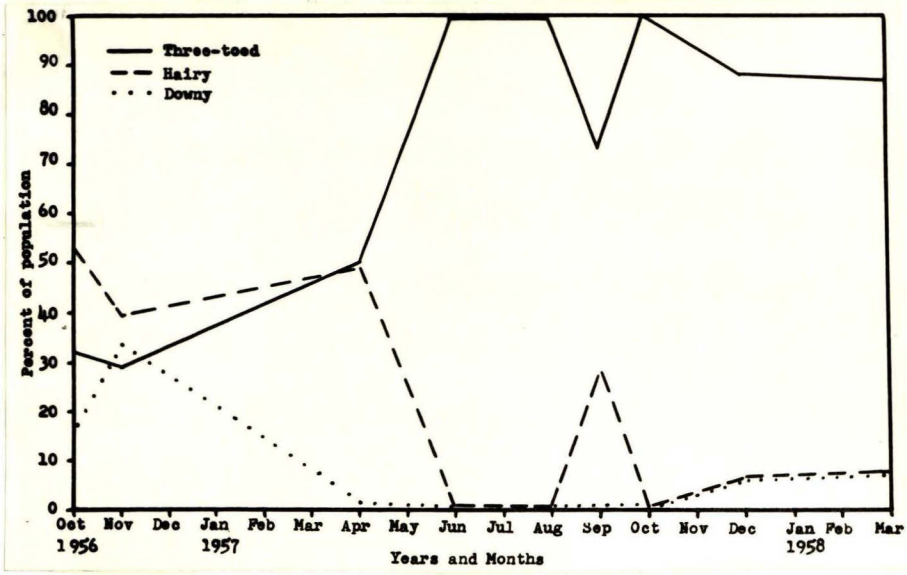

Fig. 9.--Percentages of each species of woodpecker at Wolf Creek Pass.

1958, the downys constituted seven percent of the woodpecker population. The three-toed woodpeckers tended to constitute the bulk of the population, especially after April, 1957 (Table 14, Fig. 9). The percentages computed for each species were based on the total number of woodpeckers seen during all censuses.

Hidden Valley.--No appreciable seasonal variation was noted in the population at Hidden Valley. The counts varied between zero and 0.20 woodpeckers per acre. This variation could not be related to species, as many of the woodpeckers were unidentified (Fig. 5).

Rabbit Ears Pass.--Only one woodpecker was recorded on two different occasions at Rabbit Ears Pass. No seasonal variation could be detected (Fig. 6).

Effect of weather as related to daily activity

Observations were made of the various weather conditions in which the counts were taken to determine under what conditions it would be best to take a census.

Mild weather.--During mild weather the woodpeckers began their feeding at the first light of day. They tended to feed heavily until midmorning, then to cease, except for a few birds which were found feeding during the midday hours. The woodpeckers then began

feeding about midafternoon and fed heavily until nearly dark. Figure 10 shows the typical daily feeding activity curve during clear, calm weather. The daily feeding activity curve was based on four counts, taken on October 6, 1956, while using the average-distance method along 0.2 mile of road extending through the plot at Wolf Creek Pass. While the curve is based on counts taken during a single day, this type of feeding activity was observed to be prevalent during other counts under similar weather conditions.

Snowy weather.--During snowy weather, the woodpeckers tended to feed in small numbers. The feeding occurred most frequently during the midday hours, tapering off toward evening. Hutchison (1952:56) observed similar activity while studying the effects of woodpeckers on the Engelmann spruce beetle.

On April 25, 26, and 27, 1957, censuses were taken by the average-distance method at Wolf Creek Pass between the hours of 3:30 p.m. and 5 p.m. On April 25, snow fell throughout the day and only five woodpeckers were recorded. April 26 was clear and calm with 15 woodpeckers being recorded. On April 27, the weather was again clear and calm with 17 woodpeckers being observed (Fig. 11). The birds tended to feed in large numbers during the first day or two after a storm.

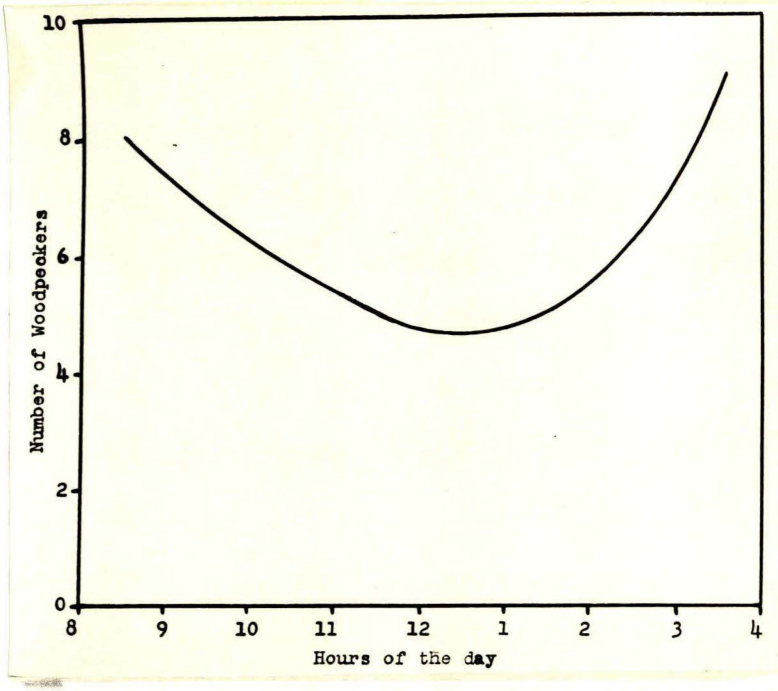

Fig. 10.--Typical daily activity curve for feeding woodpeckers during clear, calm weather at Wolf Creek Pass, October 6, 1956.

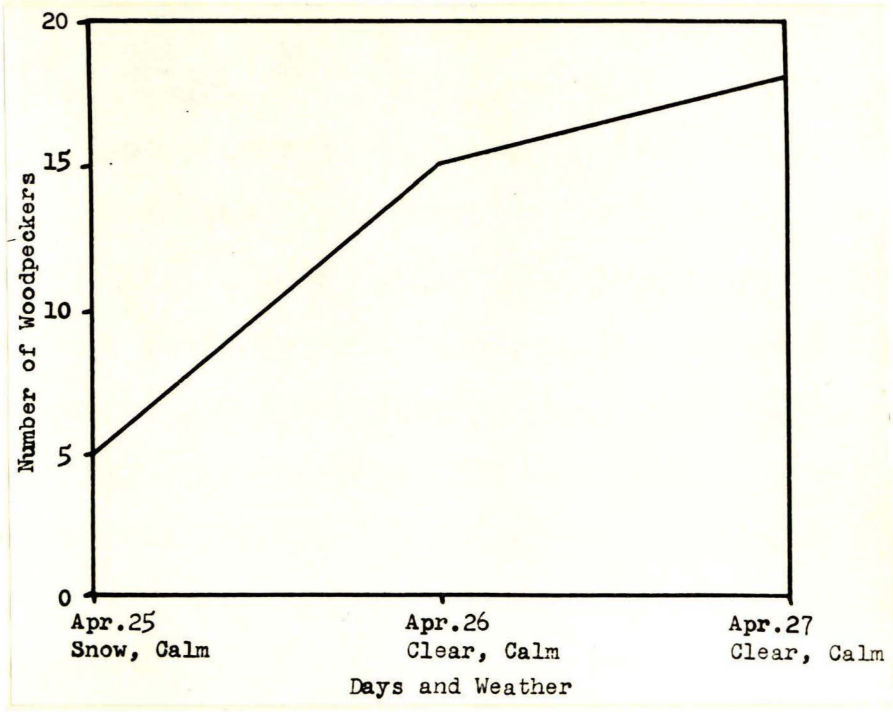

Fig. 11.--Effect of snowy weather on woodpecker feeding activity at Wolf Creek Pass, April, 1957.

Temperature.--Morning temperatures obtained on the plot at Wolf Creek Pass varied from 8°F. to 23°F. during the winter months. Evening temperatures obtained on the plot for the winter months varied from 10°F. to 27°F. Woodpeckers were observed to feed just as much at the higher temperatures as at the lower temperatures. Hutchison (1952) observed more feeding to occur at 10°F. than above 20°F.

Wind.--On days when the sky was clear but the wind was blowing the birds were difficult to locate due to the reduction in the distance at which they could be heard feeding.

Effect of Engelmann spruce beetle infestation

A very pronounced difference was observed between the numbers of woodpeckers per acre recorded at Wolf Creek Pass, Hidden Valley, and Rabbit Ears Pass. Figure 12 reveals this difference on the basis of censuses taken by the fixed-plot method. An attempt was made to determine the reason for the difference in numbers of woodpeckers found in each area. One of the primary differences observed between the three areas studied was the number of Engelmann spruce infested with the Engelmann spruce beetle. This factor was

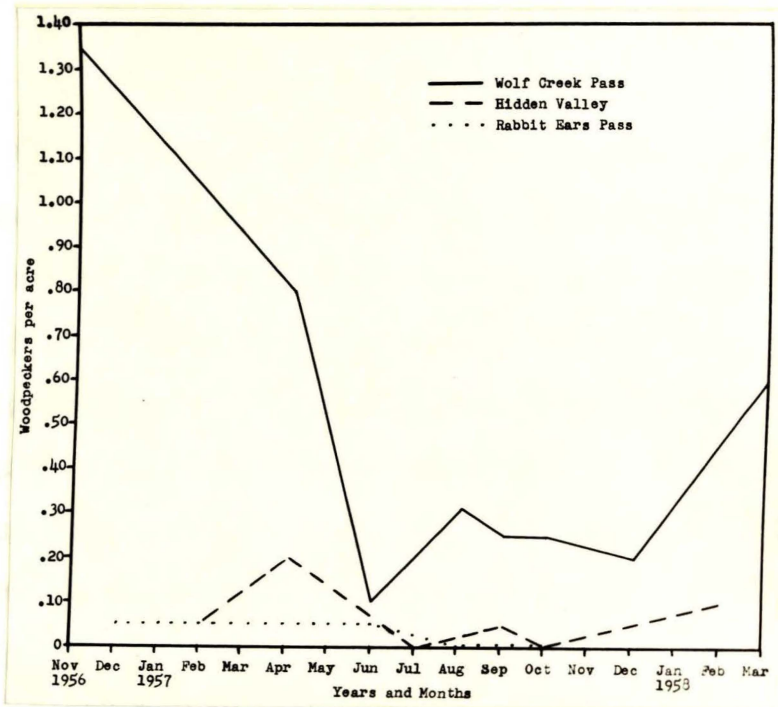

Fig. 12.--Numbers of woodpeckers recorded by fixed-plot method showing variation between areas of different classification of Engelmann spruce beetle infestation.

investigated to determine the effect that the Engelmann spruce beetle has on the population of woodpeckers of an area.

Population distribution.--Eighteen censuses were taken by the fixed-plot method at Wolf Creek Pass. Each census was summarized at the end of each acre to provide counts for the one-acre method. The counts obtained in this manner for the period from November 26, 1956, through April 27, 1957, were combined to give enough one-acre samples for the analysis of the population distribution to be made. The counts for the November to April period were combined, since there was less variability among the winter counts than if winter and summer counts had been combined. The one-acre counts were separated into groups having no woodpeckers present, those having one woodpecker present, those having two woodpeckers present, and so forth. The Poisson distribution was computed to determine if the woodpecker population was distributed in a random manner. The chi-square test revealed that the mathematical expectations computed by the Poisson method were significantly different from the actual observations. Upon computing the mathematical expectations of the negative binomial distribution, significance was not acquired. Chi-square

test gave a figure of eight percent (Table 15, Fig's. 13, 14). The chi-square test revealed that the woodpeckers were distributed in an aggregated or contagious manner.

The summer counts from June 21, 1957, through September 28, 1957, were combined and analyzed in a like manner to determine if the population distribution varied from winter months to summer months. The mathematical expectations of the Poisson distribution were shown to be significantly different from the actual observations by chi-square test. The mathematical expectations computed by the negative binomial method were less significant than were the expectations computed for the winter counts. The chi-square test gave a value of 27 percent. This indicates that the population of woodpeckers showed a more pronounced contagiousness in the summer than in the winter. The results of these analyses appear in Table 16, and Figures 15 and 16. An attempt was made to determine the reason for the contagious distribution of woodpeckers.

Correlation of woodpeckers with trees infested with the Engelmann spruce beetle.--The number of Engelmann spruce trees on each acre of the plot at Wolf Creek Pass which had been successfully attacked by the Engelmann spruce beetle in 1956 was determined in March,

Table 15.--PATTERN OF DISTRIBUTION OF WOODPECKERS AT WOLF CREEK PASS, NOVEMBER, 1956, TO APRIL, 1957, WITH NEGATIVE BINOMIAL AND POISSON EXPECTATIONS.

Class	Actual observations	Negative binomial	Poisson*
0	34	33.92	23.57
1	14	13.56	22.39
2	7	6.406	10.67
3	2	3.36	3.38
4	1	1.83	0.80
5	0	1.01	0.153
6	1	0.566	0.024
7	2	0.329	0.0032
TOTALS	61	60.981	60.9902

* Significant chi-square at 1 percent level.

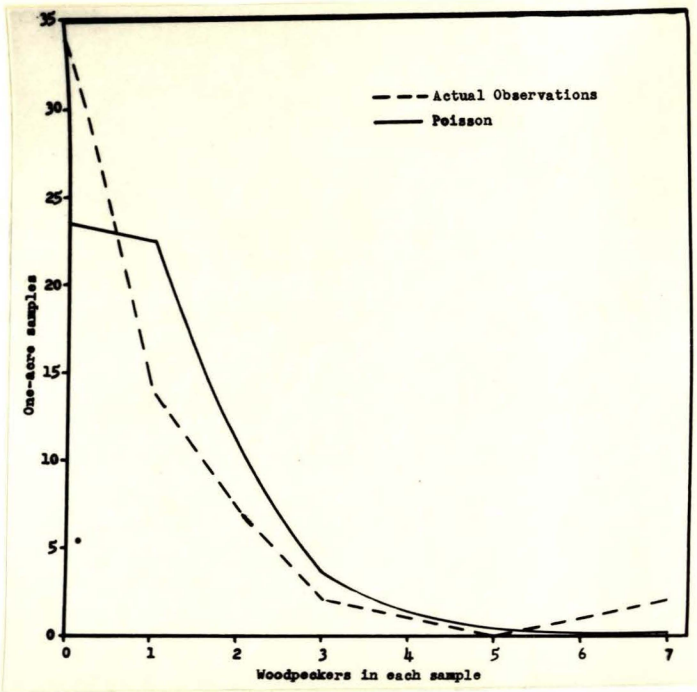

Fig. 13.--Observed woodpecker distribution with Poisson expectations, Wolf Creek Pass, November, 1956, to April, 1957.

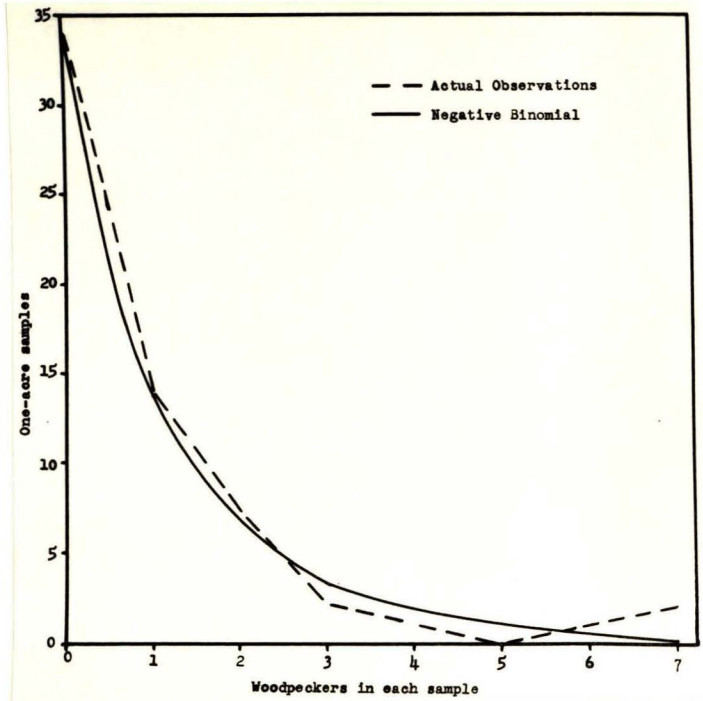

Fig. 14.--Observed woodpecker distribution with negative binomial expectations, Wolf Creek Pass, November, 1956, to April, 1957.

Table 16.--PATTERN OF DISTRIBUTION OF WOODPECKERS AT WOLF CREEK PASS, JUNE, 1957, TO SEPTEMBER, 1957, WITH NEGATIVE BINOMIAL AND POISSON EXPECTATIONS.

Class	Actual observations	Negative binomial	Poisson*
0	131	131.1000	129.1700
1	14	13.4130	16.7000
2	1	2.0490	1.0800
3	1	0.3476	0.0465
TOTALS	147	146.9097	146.9965

* Significant chi-square at 1 percent level.

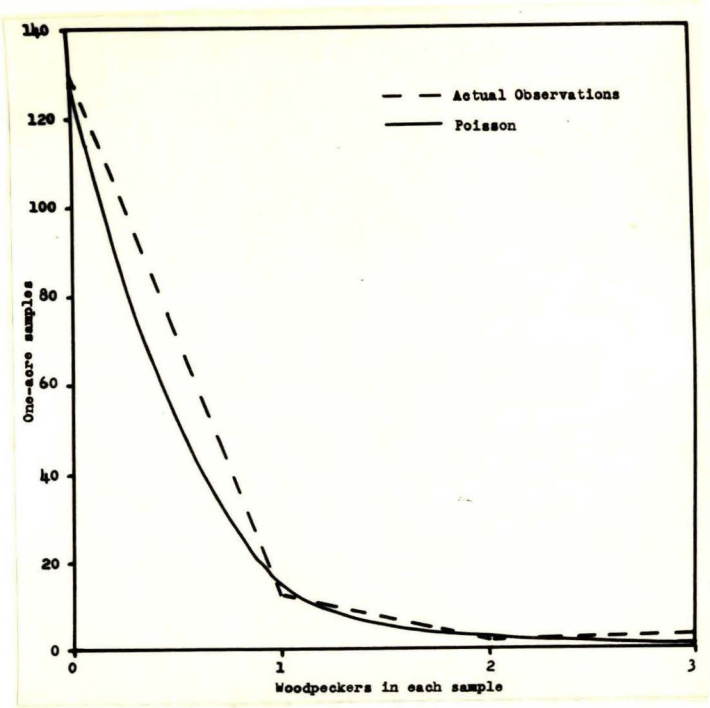

Fig. 15.--Observed woodpecker distribution with Poisson expectations, Wolf Creek Pass, June, 1957, to September, 1957.

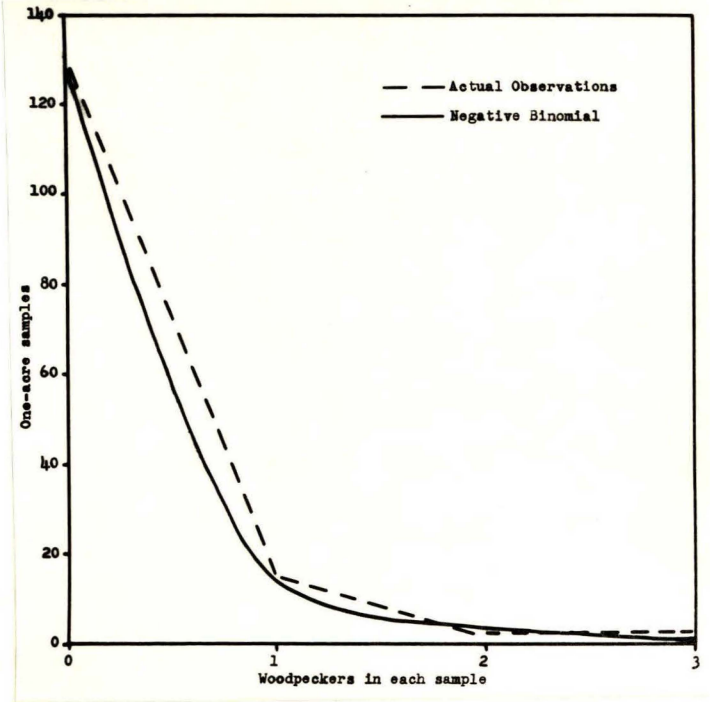

Fig. 16.--Observed woodpecker distribution with negative binomial expectations, Wolf Creek Pass, June, 1957, to September, 1957.

1958. It was not difficult to distinguish between these and previously infested spruce trees, as well as spruce killed from other causes, since many of the 1956-attacked trees still had green needles. Some 1956-attacked trees had a few brown needles persisting and nearly all of the small twigs present. Also, these trees were found to have had much of the bark removed by the woodpeckers in their search for food.

A correlation was computed to determine the relationship of the number of woodpeckers found on each acre and the number of infested Engelmann spruce trees. A significant correlation was shown to exist. This revealed a coefficient of correlation of + 0.81, which showed a close association of woodpeckers with trees infested with the Engelmann spruce beetle. Figure 17 shows a scatter diagram of these data with the regression line which was computed.

The number of woodpeckers obtained for any one acre during any one census varied from zero to seven. While seven woodpeckers seems like a large number to be present on one acre at one time, far greater concentrations of woodpeckers are believed to occur. P. H. Baldwin (personal communication) reported having seen as many as twelve woodpeckers feeding in two adjacent trees

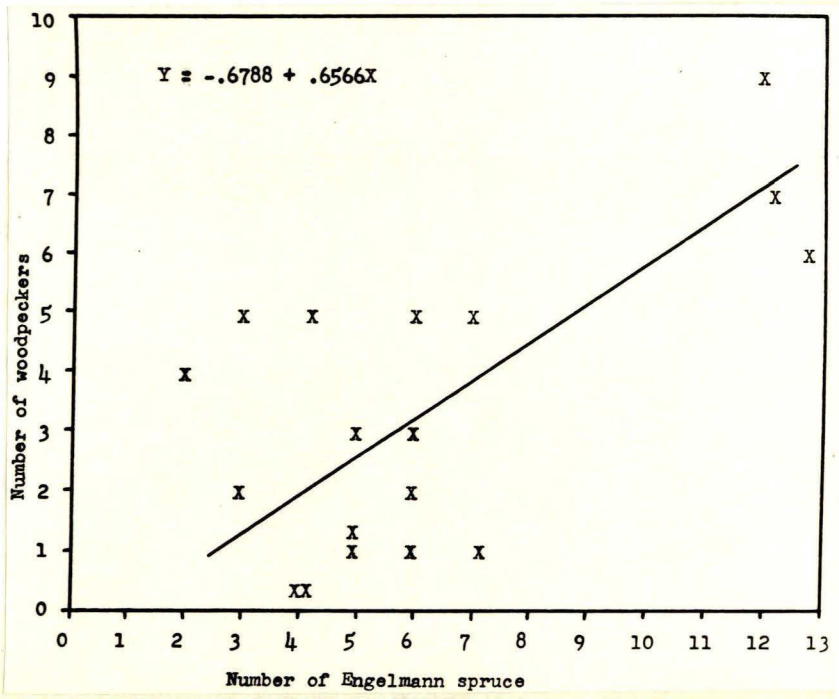

Fig. 17.--Regression of number of woodpeckers recorded on each acre and number of Engelmann spruce trees successfully attacked by the Engelmann spruce beetle in 1956.

with many more feeding in nearby trees. This occurred during the winter of 1956-57 at Wolf Creek Pass.

Summary

The stands of trees found on each 20-acre plot differed, especially in percentages of dead trees and percentages of trees infested with the Engelmann spruce beetle. Many birds were found on the plots, other than the three species of woodpeckers.

Analyses of variance showed no significant differences to exist between the fixed-plot method, one-acre method, and one-fourth-acre method with respect to the number of birds per acre and number of birds per acre per hour obtained by the use of the methods.

Several methods were used to compute the number of woodpeckers per acre using the average-distance data. The methods--modification of Hayne's, average distance of each species, and average distance of all species--gave numbers of birds per acre which differed significantly from one another. These methods gave numbers of birds per acre which were significantly larger than those derived by the method using the greatest distance of each species and the method using the average of the greatest distance of each species. The latter two did not differ significantly from one another.

Simultaneous counts were taken by several census methods. An analysis of variance showed that the modification of the method used by Hayne gave numbers of woodpeckers per acre which were significantly larger than those of the other methods, except the method using the average distance of each species and the method using the average distance of all species. The methods--average distance of each species, average distance of all species, fixed-plot, strip, average of the greatest distance of each species, and greatest distance of each species--revealed numbers of birds per acre which did not differ significantly from one another.

There were always more trees with nest holes on each 20-acre plot than woodpeckers, except on one occasion at Wolf Creek Pass. However, woodpeckers were observed to fly into the plot and some were observed to leave the plot.

Censuses taken on days of mild weather showed greater feeding activity by the woodpeckers in the early morning and in the evening. During snowy weather, activity was reduced with some feeding occurring during the midday hours. Temperatures appeared not to affect the activity of woodpeckers. On days of wind, the birds were difficult to locate.

The number of woodpeckers varied with the season, a larger number being present in the winter than in the summer.

The population of woodpeckers was characterized by the contagious distribution. The contagiousness was more pronounced during summer than during winter.

The numbers of woodpeckers were found to be closely associated with the number of Engelmann spruce trees infested with the Engelmann spruce beetle.

Chapter V

DISCUSSION

The principal objectives of this study were to determine the relative merits of each method which was used in taking censuses of woodpeckers in the spruce-fir forest and to make a comparative evaluation of these methods. Factors which were thought to affect the woodpecker population, and hence the counts, were investigated.

The habitat

Ten one-tenth-acre samples were taken on each 20-acre plot. The samples showed that a difference existed between the plots located at Wolf Creek Pass, Hidden Valley, and Rabbit Ears Pass. Variations were noted in the percentages of each species, in the percentages of dead trees, and, especially, in the percentages of trees infested with primary bark beetles. The area at Wolf Creek Pass was the only one to show a number of trees infested with the Engelmann spruce beetle.

The woodpeckers spent much time tapping and digging on the trees infested with the Engelmann spruce beetle, apparently in search of the bark beetle larvae

for food. Hutchison (1952) found that much of the food of woodpeckers, under epidemic conditions of Engelmann spruce beetle infestation, consisted of Engelmann spruce beetle larvae. At Hidden Valley, the percentage of dead trees was just as great as at Wolf Creek Pass, and the percentage at Rabbit Ears Pass was much greater than at either of the other two areas. However, the woodpecker population was observed to be much lower at both of these two areas than at Wolf Creek Pass. The woodpeckers which were present at Hidden Valley and Rabbit Ears Pass usually moved rapidly from one dead tree to another, feeding only a few seconds or just working their way over a tree as if looking for food but not feeding. The dead trees found in these areas apparently offered little in the way of insect life for food.

Other birds were found on the plot throughout the year, but no competition for food and nesting sites was noted between these birds and the three species of woodpeckers being studied. There was some evidence of predation by hawks at Wolf Creek Pass.

The fixed-plot method, one-acre method, and one-fourth-acre method

Certain variations were noted to exist between the fixed-plot, one-acre, and one-fourth-acre methods

with respect to the procedure employed in taking a census by each method and to the results obtained.

Effect of variation in procedures employed.--The fixed-plot method requires at least one day to establish the plot and to mark the paths before a census can be taken. The one-acre and one-fourth-acre methods do not require an expenditure of time in marking plots or paths. It is only necessary to choose a course through the area in which the census is to be taken and follow it with the aid of a compass. Counts can be taken at uniform distances along the course of travel. Kendeigh (1944:95) wrote that this would sample all communities in proportion to their frequency of occurrence.

The fixed-plot method showed woodpeckers to be present during every census at Wolf Creek Pass, while two zero counts were recorded at Hidden Valley and five zero counts were observed at Rabbit Ears Pass. Using the one-acre method, four counts failed to reveal the presence of woodpeckers at Wolf Creek Pass. Two counts by the same method showed no woodpeckers to be present at Hidden Valley and none at Rabbit Ears Pass. With a reduction in the amount of the plot used for the census, an increase was observed in the number of zero counts. The same held true for the one-fourth-acre method. Seven of the 15

counts at Wolf Creek Pass by the one-fourth-acre method failed to reveal the presence of woodpeckers. At Hidden Valley and at Rabbit Ears Pass no woodpeckers were recorded while using this method.

Yeager (1955:151, 153) recorded nine woodpeckers per acre in dead spruce-fir in 1949, while using the one-fourth-acre method. This figure is much higher than those obtained at Wolf Creek Pass during this study. However, greater concentrations of woodpeckers occurred at Wolf Creek Pass in the winter of 1956-57 than when the writer was present, as related by P. H. Baldwin (personal communication). Yeager obtained two woodpeckers per acre in green spruce-fir as compared to none recorded in this study while using the one-fourth-acre method at Hidden Valley. There may have been far more trees infested with bark beetles in the area of green spruce-fir than was recorded by Yeager on the actual one-fourth-acre plots he counted.

The fixed-plot method covered the entire 20 acres and consequently was more sensitive in revealing smaller numbers of woodpeckers present. Methods such as the one-acre method and one-fourth-acre method used only a portion of the 20 acres for a census. The results obtained from this portion were projected over the entire

20-acre plot, thereby assuming that the sample used in the census was representative of the whole. These latter methods tended to miss the smaller numbers of woodpeckers, especially at the endemic and past epidemic areas of Engelmann spruce beetle infestation. This undesirable effect could probably be minimized by taking a larger number of samples when using the one-acre and one-fourth-acre methods.

A variation was noted in the number of woodpeckers per acre recorded on any one day by each of the three methods. The sample counts of the area made by the one-acre method and, especially, the one-fourth-acre method had a tendency either to be zero or to show a number of birds which was much higher than that recorded by the fixed-plot method. Here again, this tendency toward distortion could probably have been minimized through taking a larger sample of the area when using the one-acre and one-fourth-acre methods.

Variation in results.--Some variation was noted with respect to the numbers of birds per acre and the numbers of birds per acre per hour obtained by the fixed-plot, one-acre, and one-fourth-acre methods. The data collected at Wolf Creek Pass were used for comparing these methods, since all three methods revealed woodpeckers to be present in that area.

The average number of woodpeckers per acre observed at Wolf Creek Pass while using the fixed-plot method was 0.30. The number for the one-acre method was 0.34, and the average number of birds per acre for the one-fourth-acre method was 0.73. These numbers show variation in birds per acre among these three methods, but an analysis of variance revealed that the variation is not great enough to show significance at the five percent level.

The number of woodpeckers per acre per hour was obtained by each of the three methods. The fixed-plot method gave a figure of 0.16, the one-acre method gave a figure of 0.29, and the one-fourth-acre method gave a figure of 0.29 woodpeckers per acre per hour. These figures reveal some difference in the numbers of woodpeckers per acre per hour as recorded by each method. However, an analysis of variance revealed that this difference was not significant at the five percent level.

These results indicate that comparable counts can be obtained, with respect to number of birds per acre and to number of birds per acre per hour, by using any one of the three methods--fixed-plot, one-acre, or one-fourth-acre.

Average-distance method

The average-distance method does not limit the observer to a specific width of strip but utilizes the greatest distance that a woodpecker can be heard tapping for food. The results obtained by this method in the area of greatest concentration of woodpeckers, in this study, were not comparable with the fixed-plot, one-acre, and one-fourth-acre methods. Several ways were used to compute the number of birds per acre based on different ways of arriving at the width of strip. These were the modification of the method used by Hayne, the method using the average distance of each species, method using the average distance of all species, method using the average of the greatest distance of each species, and the method using the greatest distance of each species.

An analysis of variance of the birds per acre computed by each method revealed that the methods--modification of the method used by Hayne (1949), average distance of each species, and average distance of all species--gave numbers of birds per acre which differed significantly from one another. These methods gave numbers of birds per acre which were significantly larger than those derived by the method using the greatest distance of each species and the method using the average of

the greatest distance of each species. The latter two did not differ significantly from one another.

The method used by Hayne was designed for pheasants or grouse, whereby only a portion of the actual population flushes. The methods--average distance of each species and average distance of all species--assume that a bird at less than the average distance is missed for every one counted beyond the average distance. Since woodpeckers are not secretive, but make considerable noise tapping and digging for food, a greater percentage of the population can be located. On the basis of this, the numbers of woodpeckers computed by the methods which correct for birds missed are too high.

The other two methods--average of the greatest distance of each species and greatest distance of each species--gave results, which are believed to be much closer to the actual numbers of woodpeckers present.

Simultaneous censuses using fixed-plot method, strip method, and average-distance method

Censuses were taken simultaneously by the fixed-plot method, strip method using a strip 66 feet wide, and the average-distance method. The data obtained by the average-distance method were used to compute the number of woodpeckers per acre by several methods--

modification of method used by Hayne, average distance of each species, average distance of all species, average of the greatest distance of each species, and greatest distance of each species.

An analysis of variance of the birds per acre computed by each method revealed that the modification of the method used by Hayne gave numbers of woodpeckers per acre which were significantly larger than those of the other methods, except the method using the average distance of each species and the method using the average distance of all species. The latter two methods and the methods--fixed-plot, strip, average of greatest distance of each species, and greatest distance of each species--gave numbers of woodpeckers per acre which did not differ significantly from one another.

While the average distance methods did not show significance from the other four methods, with a larger number of simultaneous counts, since only five were taken, significance very likely would result. The means for the five counts were 0.50 for the method using the average distance of each species, 0.44 for the method using the average distance of all species, 0.24 for the fixed-plot method, 0.28 for the strip method, 0.25 for the method using the average of greatest distance of each species, and 0.22 using greatest distance of each species. The former two are considerably larger than the other means.

Interpreting the results of the simultaneous counts in light of the counts obtained by the average-distance method used in the area of greatest concentration of woodpeckers, the modification of the method used by Hayne gives too high a count when used to census woodpeckers. This is also true for the method using the average distance of each species and the method using the average distance of all species. Kendeigh (1944:77-78) obtained indices of conspicuousness for various species, using the average of the distances for one-half the width of plot. He assumed that a bird at less than the average distance would be missed for every one seen at greater than the average distance. In this study, these methods correct for woodpeckers missed, of which there are not enough, according to the comparison with the fixed-plot method and the strip method, and the observations made, to warrant a correction of this magnitude. Admittedly, some woodpeckers were missed, but the food tapping and digging of the woodpeckers made it possible to locate nearly all the birds.

Trees with nest holes

The number of trees with nest holes was compared with the number of woodpeckers found in each area

to determine if the number of such trees had any value in attracting woodpeckers.

At Wolf Creek Pass there were more trees with nest holes present than there were woodpeckers, with the exception of one time, when there was 0.85 tree per bird. At Hidden Valley and Rabbit Ears Pass there were always more trees with nest holes than woodpeckers. Woodpeckers were observed to fly into the plot to feed and some were observed to fly off the plot at Wolf Creek Pass. One bird was followed and observed to enter a hole several hundred yards from the plot. This made it quite evident that the woodpeckers were not relying on just the trees with nest holes found on the plot. The low populations of woodpeckers at Hidden Valley and at Rabbit Ears Pass, in comparison to the number of nest holes present, indicates clearly that trees with nest holes have no special significance in attracting woodpeckers to an area. However, as a secondary factor of attraction, it seems possible that a woodpecker would more likely be attracted to an area having both an abundance of food and trees with nest holes than to one having only an abundance of food.

Seasonal variation

The difference noted between winter and summer counts of woodpeckers was very significant.

At Wolf Creek Pass, a very pronounced decrease in the population of woodpeckers was observed in April, 1957, when it was noted that nearly the entire downy woodpecker population had left the area. Another decided drop was noted in June when it was observed that neither downy nor hairy woodpeckers were present. Also, the number of three-toed woodpeckers was considerably smaller than during previous censuses. The reason for the departure of the downy and hairy woodpeckers was not determined. The departure of these species may have been associated with availability of food in the form of insects other than the Engelmann spruce beetle. The population of hairy woodpeckers was observed to increase in September. Whether this was the result of previous association with the area as an over-wintering spot with plentiful food or whether it was just an erratic wandering is not known. The number of hairy woodpeckers recorded in subsequent censuses was small, as was the number of downys.

An apparent reduction in the number of three-toed woodpeckers occurred in June. However, the three-toed species is a year-round resident, and the breeding pairs were on nesting territories in June. The lower counts for this period coincided with the spread of

the population over a larger area. An increase in the number of three-toed woodpeckers at the Wolf Creek Pass plot was revealed in August. This is probably attributable to the number of young birds which had recently been fledged. The number of three-toed woodpeckers in subsequent censuses remained relatively constant.

Effect of weather as related to daily activity

Certain observations were made at the time of taking counts to aid in determining the general effects of weather upon the population of woodpeckers. The aim of this aspect of the study was to determine the best conditions under which to take a census.

During days of mild weather, the woodpeckers fed in large numbers in the early morning and late afternoon, with a reduction in activity during the midday hours. Kendeigh (1944:90) wrote that birds are usually less active during the middle of the day. On days when snow was falling, the woodpeckers usually did not feed during the early morning and late afternoon, but fed in small numbers during the midday hours. Hutchison (1952: 56) observed similar activity while studying the food habits of woodpeckers at Rabbit Ears Pass. The first day or two following a storm the woodpeckers were out in

large numbers feeding, beginning with the first light of day. This can probably be attributed to increased hunger after not feeding during the storm. No observations were made under prolonged adverse conditions of weather, but in all probability it would only be a matter of time before the woodpeckers would be found feeding during these adverse conditions if such weather persisted. Temperature did not deem to have a significant effect upon the feeding activity, as just as many woodpeckers were observed to feed at the higher temperatures as at the lower temperatures. This is in disagreement with Hutchison (1952:56) who observed more feeding at 10°F. than above 20°F.

Wind reduced the distance that the woodpeckers could be heard and consequently the number which was located. This is in agreement with the effect of wind noted by Phillips and Black (1956:403) in their study of the Winter Wren. Colquhoun (1940:56) also observed a reduction in conspicuousness of birds under conditions of wind.

The best time to take a census during mild weather is in the early morning or late afternoon. The day or two after a storm are good days for censusing, since the birds are out in large numbers after apparently

"holing up" during the snow. Temperatures, within the limits encountered in this study, appear not to affect the feeding activity of the woodpeckers. Taking a census should be avoided when the wind is blowing, since few woodpeckers can be located.

Effect of Engelmann spruce beetle infestation

One of the main differences between the areas studied was the amount of Engelmann spruce beetle infestation in each.

A positive correlation, with a coefficient of correlation of +0.81, existed at Wolf Creek Pass for the number of woodpeckers recorded on each acre and the number of trees successfully attacked by the Engelmann spruce beetle in 1956. This indicates that the presence of woodpeckers is closely associated with the Engelmann spruce beetle, upon which woodpeckers were observed to spend much of their time feeding. The fact that no trees infested with the Engelmann spruce beetle were found at either Hidden Valley or Rabbit Ears Pass, combined with the low population of woodpeckers, makes quite evident the value of attraction that the Engelmann spruce beetle population of an area has for woodpeckers.

An analysis of the distribution showed that the woodpeckers were dispersed in a contagious or aggregated

manner. In view of the findings of Cole (1946) on the contagious distribution of many invertebrates, similar reasons must be considered in attempting to explain the contagious distribution of birds.

Food supply is probably one of the main factors accounting for the contagious distribution characteristic of the population of woodpeckers at Wolf Creek Pass during the winter. A more pronounced contagiousness was observed during the summer months than during the winter months. In addition to the effect of the Engelmann spruce beetle, it is very possible that the effect of formation of territories during the breeding season was superimposed upon food supply. This would account for the increase in contagiousness of the population of woodpeckers.

Suggestions for further study

1. It would be of value as an extension of this study to test the same census methods with other species of forest birds to learn more about the importance of conspicuousness and other factors which affect the counting of particular species of birds.

2. An application of the methods, shown in this study to be most appropriate for censusing

woodpeckers, at various distances from a new epidemic of the Engelmann spruce beetle might possibly determine the movement of woodpeckers into the epidemic area. This would give information on the distances at which woodpeckers can be attracted to an epidemic of bark beetles, along with the length of time necessary for the movement of the birds into the infested area to occur.

3. The distribution within habitats of other species of birds should be investigated and the reasons for the particular pattern determined. This might aid in determining the conspicuousness of the species and thereby influence the selection of the method to be used in censusing that species.

Chapter VI

SUMMARY

Artificial means to control harmful forest insects have been used extensively in past years. However, such control operations have become increasingly expensive. This has consequently focused attention on natural control factors of these insects.

Woodpeckers are considered by forest entomologists to be the most important predator of the Engelmann spruce beetle. This study was undertaken to investigate the merits of various methods for taking censuses of woodpeckers and to determine the factors which affect the counting of woodpeckers. With more accurate information on the numbers of woodpeckers it is thought that the effectiveness of the woodpeckers as a biological control factor of the Engelmann spruce beetle can be more accurately determined.

Studies have been made on methods for taking censuses of birds; however, review of literature failed to reveal studies specifically applied to woodpeckers and the factors involved in the counting of woodpeckers. Four main methods were used in taking the censuses.

These were the fixed-plot method, one-acre method, and one-fourth-acre method, which were used at Wolf Creek Pass, Hidden Valley, and Rabbit Ears Pass. The average-distance method was used only at Wolf Creek Pass. The strip method was used a limited number of times at Wolf Creek Pass. Several different ways of computing the woodpeckers per acre using the data collected by the average-distance method were used. These were a modification of the method used by Hayne for pheasants, the method using the average distance of each species for one-half the plot width, the method using the average distance of all species for one-half the plot width, the method using the average of the greatest distance of each species for one-half the plot width, and the method using the greatest distance of each species for one-half the plot width. All of the methods for censusing woodpeckers were used while walking along the marked paths of the 20-acre fixed plots. The average-distance method was also used along a road which passed through the plot at Wolf Creek Pass.

The distances from the path at which woodpeckers were counted varied with the method. The distance for the fixed-plot and one-acre methods was 66 feet on each side of the path. The one-fourth-acre method

employed a circular plot 120 feet in diameter. While using the strip method, a distance of 33 feet on each side of the path was counted. The average-distance method permitted the counting of woodpeckers for as far as they could be heard. Analyses of variance were made to test the results obtained by the various methods.

Various factors were investigated to determine their effect on the woodpecker populations and hence, the counts. Censuses were made during the different seasons, under various weather conditions, and during different hours of the day. Other factors which were investigated were the number of trees with nest holes found on each 20-acre plot, the number of Engelmann spruce trees which were infested with the Engelmann spruce beetle, the behavior of woodpeckers, and the distribution of woodpeckers.

Results obtained

Results obtained from the application of these methods and the investigation of factors affecting the population of woodpeckers are summarized below.

Methods of censusing.--1. The fixed-plot method, one-acre method, and one-fourth-acre method did not vary with respect to the number of woodpeckers per acre

and the number of woodpeckers per acre per hour revealed by each.

2. The fixed-plot method requires time consuming preparation before a census can be made, such as establishing the plot and marking of paths. The one-acre and one-fourth-acre methods require only following a straight line through an area with the aid of a compass and taking counts at intervals along the line. The average-distance method does not limit counting to a restricted width of plot but makes it possible to record all woodpeckers seen or heard.

3. The fixed-plot method sampled the area more intensively, making it possible to record woodpeckers when the number was small. The one-acre and one-fourth-acre methods tended to miss the smaller numbers of woodpeckers.

4. The methods--modification of Hayne's, average distance of each species, and average distance of all species--gave numbers of birds per acre which differed significantly from one another. These methods gave numbers of birds per acre which were significantly larger than those derived by the method using the greatest distance of each species and the method using the average of the greatest distance of each species. The latter two did not differ significantly from one another.

5. Simultaneous counts revealed that the modification of the method used by Hayne gave numbers of woodpeckers per acre which were significantly larger than those of the other methods, except the method using the average distance of all species, and the method using the average distance of each species. The methods--average distance of all species, average distance of each species, fixed-plot, strip, average of the greatest distance of each species, and the greatest distance of each species--revealed numbers of birds per acre which did not differ significantly from one another.

6. Table 17 is a comparison of the four main methods used in this study.

7. In this study the method using the greatest distance of each species for one-half the plot or strip width was found easy to apply and is recommended for use under similar conditions. This method requires only the following of a compass line through the area to be censused. It does not limit counting to a definite width of strip, but allows the census taker to record all woodpeckers seen or heard. The results of this method, as shown in this study, are comparable to those derived for the fixed-plot method.

Table 17.--COMPARISON OF THE FOUR MAIN CENSUS METHODS AS USED IN THIS STUDY.

Factors	Fixed-plot method	One-acre method	One-fourth-acre method	Average-distance method
Advanced preparation	much	little	little	little
Number of acres covered in relation to time spent	many	many	few	many
Adequacy of coverage of area	good	fair	poor	good
Limited to predetermined size of plot	yes	yes	yes	no
Sparse woodpecker population	good	fair	poor	good
Heavy woodpecker population	good	good	good	good
Comparison of results with other three methods	comparable	comparable	comparable	too high

Factors affecting counts.--1. Trees with nest holes apparently had little value in attracting woodpeckers to the areas investigated in this study.

2. Seasonal fluctuations occurred in the woodpecker population at Wolf Creek Pass, with the greatest number being present in the winter. This fluctuation was brought about by the departure of the hairy and the downy woodpecker populations and through the dispersal of the three-toed woodpeckers by the establishment of territories.

3. During clear, calm weather, the greatest number of woodpeckers was observed to be actively feeding in the early morning and the late afternoon.

4. On snowy days fewer woodpeckers were found than on days of good weather. The feeding activity was greatest during the midday hours.

5. The first day or two after a snow storm the woodpeckers were found feeding in large numbers.

6. Temperatures encountered in this study did not affect the feeding activity of woodpeckers.

7. Wind made it difficult to hear the woodpeckers and consequently caused a reduction in the number of woodpeckers recorded.

8. Nearly all woodpeckers were located by the noise they created while tapping and digging for food.

9. The woodpeckers were distributed in a contagious manner. The contagiousness was more pronounced in summer than in winter.

10. A coefficient of correlation of +0.81 reveals a close association of the number of woodpeckers found on each acre with the number of Engelmann spruce trees which was successfully attacked by the Engelmann spruce beetle in 1956.

A P P E N D I X

Appendix A.--HABITAT SAMPLE

Appendix A.

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Appendix A.

Table 1.--ONE-ACRE SAMPLE OF HABITAT AT WOLF CREEK PASS SHOWING LIVING, DEAD, AND INFESTED TREES.

Inches D.B.H.	Engelmann Spruce			Sub-alpine Fir		
	Liv.	Dead	Inf.	Liv.	Dead	Inf.
5-7	57	3	0	7	0	0
7-9	40	5	1	11	0	0
9-11	33	8	1	3	0	0
11-13	35	7	2	1	0	0
13-15	22	8	2	2	0	0
15-17	27	6	1	2	0	0
17-19	14	6	2	0	0	0
19-21	5	3	2	0	0	0
21-23	3	2	1	0	0	0
23-25	1	3	1	0	0	0
25-27	3	2	1	0	0	0
27-29	1	0	0	0	0	0
TOTALS	241	53	14	26	0	0
PERCENT	72.20	15.80	4.20	7.80	0.00	0.00

Appendix A.

Table 2.--ONE-ACRE SAMPLE OF HABITAT AT HIDDEN VALLEY SHOWING LIVING, DEAD, AND INFESTED TREES.

Inches D.B.H.	Engelmann spruce			Sub-alpine fir			Lodgepole pine			Limber* pine
	Liv.	Dead	Inf	Liv.	Dead	Inf	Liv.	Dead	Inf	Liv.
5-7	65	5	0	38	9	0	20	0	0	1
7-9	46	3	0	24	15	0	16	5	0	11
9-11	23	2	0	6	12	0	13	5	0	4
11-13	19	1	0	3	5	0	9	5	0	2
13-15	12	0	0	2	4	0	4	1	0	2
15-17	5	0	0	0	1	0	0	0	0	0
17-19	2	0	0	0	0	0	0	0	0	0
19-21	3	0	0	0	0	0	0	0	0	0
TOTALS	175	11	0	73	46	0	62	16	0	20
PERCENT	43.4	2.7	0	18.1	11.4	0	15.4	4.0	0	5.0

* All limber pine were live trees.

Appendix A.

Table 3.--ONE-ACRE SAMPLE OF HABITAT AT RABBIT EARS PASS SHOWING LIVING, DEAD, AND INFESTED TREES.

Inches D.B.H.	Engelmann spruce			Sub-alpine fir			Lodgepole pine		
	Liv.	Dead	Inf.	Liv.	Dead	Inf.	Liv.	Dead	Inf.
5-7	11	7	0	18	2	0	5	2	0
7-9	10	8	0	19	1	0	6	1	0
9-11	6	7	0	18	0	0	5	1	0
11-13	4	7	0	7	0	0	9	3	0
13-15	1	15	0	8	0	0	8	1	0
15-17	1	8	0	2	0	0	5	1	0
17-19	4	4	0	1	0	0	4	0	0
19-21	1	0	0	2	0	0	1	0	0
21-23	2	2	0	1	0	0	1	2	0
23-25	0	1	0	0	0	0	0	0	0
25-27	0	0	0	0	0	0	0	0	0
27-29	0	0	0	0	0	0	0	0	0
29-31	0	1	0	0	0	0	0	0	0
TOTALS	40	60	0	76	3	0	44	11	0
PERCENT	17.1	25.6	0.0	32.5	1.30	0.0	18.8	4.7	0.0

Appendix B.--BIRDS PER ACRE PER HOUR

Appendix B.

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Appendix B.

Table 1.--NUMBERS OF WOODPECKERS PER ACRE PER HOUR OBTAINED BY FIXED-PLOT METHOD AT WOLF CREEK PASS.

Date	Number of acres	Hours & minutes	Number of birds	Birds per acre per hour
11-26-56	20	2-57	27	0.46
4-26-57	20	3-57	16	0.20
4-27-57	20	2-31	14	0.28
6-21-57	12	0-43	1	0.12
6-22-57	20	1-39	2	0.06
8-15-57	20	1-40	2	0.06
8-15-57	12	0-51	4	0.39
8-28-57	12	0-28	1	0.18
9-9-57	12	0-37	2	0.27
9-27-57	20	1-25	1	0.04
9-27-57	20	1-22	3	0.11
9-28-57	20	1-51	5	0.14
10-11-57	20	1-18	1	0.04
10-12-57	20	1-18	5	0.19
12-17-57	20	1-37	1	0.03
12-18-57	20	1-15	2	0.08
12-19-57	20	1-44	4	0.01
3-18-58	20	2-10	12	0.28
TOTALS	328	29.39	103	2.96
MEANS	18.22	1.63	5.72	0.16

Appendix B.

Table 2.--NUMBERS OF WOODPECKERS PER ACRE PER HOUR OBTAINED BY ONE-ACRE METHOD AT WOLF CREEK PASS.

Date	Number of acres	Hours & minutes	Number of birds	Birds per acre per hour
11-26-56	10	1-38	15	0.92
4-26-57	10	2-08	11	0.51
4-27-57	10	1-25	10	0.70
6-21-57	6	0-31	0	0.00
6-22-57	10	0-55	1	0.11
8-15-57	10	1-00	2	0.20
8-15-57	6	0-36	4	1.11
8-28-57	6	0-24	0	0.00
9-9-57	6	0-29	1	0.35
9-27-57	10	0-53	0	0.00
9-27-57	10	0-51	2	0.24
9-28-57	10	1-05	1	0.09
10-11-57	10	0-49	0	0.00
10-12-57	10	0-49	3	0.37
12-17-57	10	0-58	1	0.10
12-18-57	10	0-48	1	0.13
12-19-57	10	1-02	2	0.19
3-18-58	10	1-40	3	0.18
TOTALS	164	17.02	57	5.20
MEANS	9.11	0.95	3.17	0.29

Appendix B.

Table 3.--NUMBERS OF WOODPECKERS PER ACRE PER HOUR OBTAINED BY ONE-FOURTH-ACRE METHOD AT WOLF CREEK PASS.

Date	Number of acres	Hours & minutes	Number of birds	Birds per acre per hour
10-6-56	2.50	3-00	3	0.40
11-24-56	2.50	3-00	10	1.33
4-25-57	3.50	5-04	1	0.06
4-27-57	2.50	2-30	3	0.48
6-23-57	3.00	1-46	1	0.19
8-15-57	2.25	1-12	0	0.00
9-10-57	2.50	1-09	2	0.69
9-27-57	2.50	1-22	0	0.00
10-11-57	2.50	1-19	0	0.00
10-12-57	2.50	1-08	0	0.00
12-17-57	2.50	1-08	0	0.00
12-18-57	2.50	1-22	3	0.87
12-19-57	2.50	1-17	0	0.00
12-20-57	5.00	2-26	0	0.00
3-19-58	5.00	2-30	4	0.35
TOTALS	43.75	30.22	27	4.37
MEANS	2.92	2.01	1.80	0.29

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